THE

JOURNAL OF GEOLOGY

OCTOBER–NOVEMBER, 1898

THE CLASSIFICATION OF STRATIFIED ROCKS.

THE problem opened for discussion in the "Symposium on Classification, etc," in the May–June number of the JOURNAL OF GEOLOGY is much wider than the compass of the particular questions raised. It was by no means lack of interest in this problem, or in the particular questions, that led the writer to refrain from participation in the symposium. My opinion, then as now, was that the real difficulties in the case will not be solved by reaching even uniform replies to the questions; and further, the meeting which was held in September, of the International Commission on Stratigraphic Classification, which I then expected to attend, was another reason for delay in expressing an opinion till after the meeting of the commission.

Taking up the subject, where it was opened in the "Symposium," I will attempt first to give a reply to the preliminary question, raised in the introduction by the following sentence, viz.:

"Granting that these questions cannot be answered finally at present, or in the near future, it is still urgent to inquire: *By the use of what system, provisionally adopted for current use, can we best work on toward better systems in the future?*"[1] In framing a reply to this question, let me first call your attention to the steps already taken toward the construction of a provisional system of general classification and nomenclature for stratified rocks.

It will be remembered that in 1878, twenty years ago, the

[1] JOUR. GEOL. Vol. VI, p. 334.

first International Congress of Geologists met in Paris. The chief purpose of this congress, as set forth in the first article of its programme was, "*Le'unification des travaux géologique au point de vue de la nomenclature et du figure*," which in English is — the attainment of uniformity in the naming, classifying and mapping of geological facts. At Paris papers were read and discussions were held, but few results were reached beyond the appointment of commissions to prepare for definite future work. At the second meeting, held in Bologna in 1881, a commission was appointed with power delegated to take the necessary steps for the making of a geological map of Europe. The discussions at this congress and at the next, held in Berlin in the year 1885, and the work of the commissions meeting at Foix in 1882, at Zurich in 1883, at Geneva in 1886 and at Manchester in 1887, all were directed toward the perfecting of a system of nomenclature, classification and cartography upon which to construct this European map. The map necessarily covered the territory of a number of independent states, whose geological surveys had been carried on independently by men speaking in several different tongues, and it was necessary to reach uniformity in nomenclature and method of representation of the facts for all these European states, in order to construct that map. Although the map was not then complete, at the time of meeting of the London Congress in 1888, the great majority of the disputed questions had been settled. In many cases the agreements were rather compromises, necessitated for the execution of a common map, than real settlement of the disputed points, or the attainment of actual uniformity in usage.

Thus the European classification and nomenclature, as set forth in the decisions of the congresses previous, it may be said, to St. Petersburg, were incident to the preparations of a geological map of Europe, and should not be regarded as constituting a universal scheme, any more than that devised for the preparation of a geological map for a similarly restricted area in another continent. Some American geologists realized this fact and, while taking deep interest in the discussions and the

expression of the views of their fellow workers, saw no reason for interference with, or the taking of an active part in, the solution of questions which pertained so largely to European geology. It was evident, to one watching the work of the congress, that the difficulties and dissent increased as the territory under consideration enlarged. England and Russia whose domains lay farthest from the center of Europe had greater difficulty in adjusting their classifications and nomenclatures to the common scheme than did the diverse states situated in the central part of Europe; and the geologists of the United States, most of all, have found insurmountable difficulties to the complete application of the European scheme to their own work. After the questions relative to the construction of the geological map of Europe were settled, this general dissatisfaction with attempts to settle questions of science by majorities resulted, at the London meeting, in the decision no longer to settle questions of general debate by formal votes; and in the following congresses, at Washington, Zurich and St. Petersburg, only such questions as had been submitted for consideration to commissions, and were carefully formulated, were put to formal vote of the body of the congress.

While these things were going on in the congress, the geologists of the United States were active along the same lines in their own country.

A few American geologists attended the Berlin Congress in 1885, and prepared a detailed English report of the proceedings. (The official proceedings of the congresses have been reported in French.) After their return an American committee, composed of fifteen geologists, set to work to prepare a report on the classification and nomenclature then in use in America. This report was submitted at, and published as a part of the proceedings of, the London Congress in 1888. In this report, the state of progress toward uniformity in the United States, of both nomenclature and classification of stratified rocks was given in summary form; and some of the difficulties and diversities in usage were pointed out. Following this, and probably suggested by one of

the chapters of the report, a Division on Correlation, as a distinct department of the survey, was organized by the Director of the United States Geological Survey. A series of bulletins were published (Nos. 80–86), in which a thorough discussion was made of the historical development of knowledge, nomenclature, and classification of each of the grand systems of the geological column on the American continent. The first "essay" was published at the time of the Washington Congress, in 1891. Two of the volumes contemplated have not been published at the present date. Each of them was prepared by a specialist and was based upon thorough study of literature and knowledge of the facts.

In this series of essays, the fact was clearly demonstrated, (which had been already announced for the Devonian in the American committee's report) that the formations of each one of the grand geological systems present such great diversity in physical features and even in the particular composition of their faunas, that two, three, and, in some cases, four distinct classifications, with as many sets of different names are needed to represent the true state of facts regarding each one as known to science at the present time, in the United States alone.

The first of this series of bulletins on correlation was issued in 1891, at the time of the meeting of the International Congress of Geologists at Washington.

While the European geologists were struggling with the various difficulties arising in the attempt to put the geological features of the various states of Europe onto a single map, with a single system of color conventions and a common legend, the United States Geological Survey was dealing with similar problems on the continent of North America. Not only was the territory covered by the work of the United States Geological Survey quite as vast as that covered by the map of Europe (the total area of Europe being 3,800,000, and that of the United States being 3,536,290), but the geology in the several states in America is found to present a greater variety of expression and more complete diversity of composition than is expressed in the states

of Europe altogether. So that the members of the United States Geological Survey, in their own legitimate work, have been obliged to consider as wide problems as have engaged the International Congress of Geologists, whose preponderating majority is made up of European members.

As early as 1881 a cartographic system was devised by the survey for the preparation of its maps. This was described in the second annual report of the survey and also was communicated to the Second International Congress meeting at Bologna in 1881. As happened to similar schemes presented by representatives of the various Europeans, this was a provisional scheme whose modification was the natural result of their comparison at the meetings of the congress, and the trials of the system in actual mapping of widely diverse problems.

In the years 1889–90 the importance of a uniform and established scheme for all the maps of the United States led to the holding of a "Conference on Map Publication," which was called by the Director of the Survey, was composed of nineteen of the most experienced and ablest geologists of the country, and was held in Washington, in January 1889,

As a result of this conference a scheme of classification and set of rules for use in mapping the results of the work of the United States Geological Survey were prepared. These rules were published in the Tenth Annual Report in 1889, and have been the basis upon which the reports and maps of the survey have been constructed since then. The scheme differs from the European scheme adopted by the International Congress in many particulars. The difference which is most striking on comparing the two, has relation to the principle of uniformity itself. The European system is built on the assumption that uniformity in nomenclature is practicable, and should be attained as far as consistent with the divergent opinions and practices of the various states concerned. The United States system is fundamentally elastic, and rests on the general assumption that uniformity is practicable only in respect to the grander divisions, and that diversity in both naming and classifying the subdivisions of

the geological systems is both practicable and necessary to the true representation of the facts in the case.

It is this fundamental characteristic of the United States scheme which furnishes the answer to the question quoted at the beginning of this article from the "Symposium" of a few months ago. The system which should be adopted provisionally for current use, both by geological workers and by teachers, must recognize this fundamental fact, that the units which it is attempted to name and classify in stratigraphical geology, are not constant units, presenting uniform characters for the whole world or for each continent, but are very inconstant, preserving the same characters for only very limited areas.

Since this is known to be the actual fact regarding geological formation, it is useless to attempt to hold to a rigid system of nomenclature, or to raise the vain hope that the use of the same names will help us over the difficulties arising from the great diversity of facts.

Having recently attended the meeting of the International "*Commission des classifications stratigraphiques*" in Berlin, it is with great pleasure that I am able to report that the commission appointed at the St. Petersburg Congress adopts this principle of elasticity in all matters of detail as a foundation principle in the construction of rules for use in discussing international stratgraphy. Professor Renevier, the chairman of the commission, has not yet published his official report of the proceedings, hence I will not attempt the discussion of details until the report is received. But I believe it will interest all American geologists to know, that several principles, which we believe in, and on account of which has arisen some of our dissatisfaction with the European nomenclature and classification adopted by the International Congress for the map of Europe, will be recommended as the basis of an international system of classification.

One of these points is the recognition that the so-called systems, or units of the second order, are the smallest divisions of the geological scale to which uniform names and position in the classification can be given in an international scheme.

A second point is that, even in the definition of these systems, a degree of elasticity must be left for the geologists of different continents and countries.

A third point is the adoption of a set of prefixes (*Paleo*, *Meso* and *Neo*) to be attached to the name of the system as a method of reaching comparative uniformity in the naming of divisions of the third order.

The fourth point is the leaving to the local geologist, the task of selecting local geographic names for the divisions of the fourth order.

Other points were discussed, but these are sufficient to show the trend of the discussions.

When the report of the commission is published, a fuller presentation of the matter will naturally occur, but until then it seems to the writer that any attempt to make a more rigid classification or nomenclature for general purposes is not to be desired.

What we all are striving for is a scheme of nomenclature and classification by which we can clearly express and represent the grander conclusions of our science which are at present so much hidden by the multitude of details. But it is necessary to bear in mind, while seeking to attain this end, that refinement or uniformity in classification, or in methods of representing the facts, will not discover the principles coördinating and determining the relations of these facts to each other. The system of our classification must be based upon the knowledge already possessed, and so long as we have not discovered the clue to the great diversity presented by stratigraphic units, we must retain all the diversity they express in our detailed descriptions of them, and wait for uniformity in respect to the lesser matters until we discover the principles upon which the diverse phenomena are bound together into a systematic whole.

It must be realized that many of these diversities, in name and relations to each other of the facts of geology, which confuse the student as his studies extend to details of the geology of other areas and other countries, are not due to different usage,

language, or understanding, but to actual diversity in the facts themselves, which only wide and profound studies in comparative historical geology can reduce to a system. When, therefore, we attempt to speak of geological events in their chronological relations, the known truth can be expressed only by an elastic use of a universal scale whose divisions are few, and whose boundaries are not precise.

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NEW HAVEN, CONN.
October 28, 1898.

THE SO-CALLED CRETACEOUS DEPOSITS IN SOUTH-EASTERN MINNESOTA.

THE extent of Cretaceous formations in Minnesota has not yet been exactly determined. Small areas of the Cretaceous are known to be extant in several places and also large areas are believed to lie hidden under the drift in the western half of the state, adjacent to or continuous with the Cretaceous formations which occur in North and South Dakota and Iowa. In the region where large extent of Cretaceous is thought to exist in Minnesota, the glacial drift is very deep and the underlying formations are little, or not at all, accessible. In other regions where there is generally less drift, there is not much Cretaceous deposit. A few isolated areas only are reported to be Cretaceous-covered and these alone attest whether or not the Cretaceous deposits to the westward of Minnesota had once extended quite continuously eastward in the state to or beyond the central portions, as some geologists have thought. As far as has been ascertained, all known outcrops might well belong to local or even inland deposits. Again, whatever its extent, the Cretaceous now lies, when present, always immediately beneath the glacial drift and in this position it might presumably be found strongly eroded, and, therefore, we not only do not know the original extent of Cretaceous sedimentary deposits in Minnesota but also we cannot safely predict how much of that unknown quantity might now be extant.

The known extent of the Cretaceous in Minnesota is very small, while the sometimes estimated extent is very large. This statement may be well illustrated by reference to the final reports of the Minnesota Geological Survey, in which the maps of the several counties in volumes one and two, represent a few scattered spots of known Cretaceous, while the map of the state, in volume three, which is constructed from the same data

shows one-half the area to be probably Cretaceous, beneath the drift. Further geological investigation must of course tend to lessen this enormous difference between the known and the possible Cretaceous. During the last two summers I have had opportunity to investigate the supposed Cretaceous in southeastern Minnesota with the surprising result that the reported areas and deposits, in some instances prove to be doubtful.

In this region, there have been mapped, as mentioned, probable Cretaceous areas, covering a small spot in Goodhue county, patches in Fillmore county, and a continuous area in Steele, Dodge, Mower, Freeborn, Faribault, Blue Earth, Brown and other counties. The reported known areas are that of Goodhue county, some clays in Mower county, near Austin, and gravels near Hamilton, small pockets of clay in Blue Earth and Scott counties and certain strata in Brown and Nicollet counties.

The last named is very probably Cretaceous. Near New Ulm, Brown county, have been found fossil leaves which are described by Leo Lesqueseaux[1] and referred by him to the Dakota group. I have visited the same locality and collected some of these fossils, which are abundant only in a thin discontinuous stratum of fine sandstone. The whole bed, consisting of coarse sand with some irregularly distributed clay is 30 feet or more thick and rests upon a rotted granitoid rock, which rises 10 feet above the level of the Cottonwood River. The fossil leaves were found a few feet only above the sandstone's base, in a layer which has a concretionary-like surface, and except for its width of several feet might be called a pebble, which other smaller fossil-bearing concretionary masses in the same zone certainly appear to have been. The leaves are found therefore in a broken stratum, which, however, was, with little doubt, contemporaneously deposited and broken, so that the contained flora is indicative of the formation's age. The materials of the sandstone are imperfectly asssorted and again almost arcose in character.

Other sand and clay exposures of the same age have been des-

[1] Minn. Geol. Surv., Vol. III.

cribed from the neighborhood of New Ulm on the Minnesota River, but since they have afforded no further conclusive evidence, and since they too lie on the border or outside of what should be called southeastern Minnesota, I pass them by. Again, the supposed Cretaceous, which occurs farther down the Minnesota River valley at and below Mankato, might be passed perhaps justly with a denial that it is Cretaceous. Of course Cretaceous materials and fossils may be found in drift there and elsewhere in the state. But the beds of fine clay, containing some sand, which are on and in the Shakopee and Oneota dolomite formations, bear no fossils. They are like mere pockets of residuary clays from limestones and dolomites. They occur as white or variegated clays in the seams or in pockets or resting irregularly upon the iron-stained surfaces of the dolomites. Gravels of later age, possibly from early glacial drift, have been also described as Cretaceous, while others are possibly early Pleistocene, possibly Cretaceous. There is little or no conclusive evidence of the age of these small deposits. They need therefore no detailed description here, but a full account of them can be found in Final Report, Vol. I, p. 432; Vol. II, p. 127, Minnesota Geological Survey.

The reported Cretaceous at Austin, Mower county, is more important, because upon its character has depended the coloring of several counties on the geological map. Austin lies about 60 miles southeast of Mankato, 85 miles therefore in the same direction from New Ulm. The map coloring from Mankato to Austin depended upon the occurrence of supposed Cretaceous at Austin. Here occurs a variegated clay ranging in color from pea-green to bright red and yellow, resting upon a limestone or dolomite of Devonian age. It has not however been found in place, but is always, as far as known, involved in the glacial débris. Whatever the origin of this clay, it is now glacial drift, a Pleistocene deposit, and therefore not properly to be mapped as Cretaceous.

Regarding the question whether or not these clays were derived from Cretaceous formations, it must be said that the evi-

dence indicates strongly that they were not. For example, a large pit opened by the Austin Brick and Tile Works showed about ten feet of clay of all colors jammed together, bearing bowlders of granite, especially in the upper part, and large blocks of Devonian limestone, especially in the lower part. There is no mistaking the blocks of limestone, for they pass gradually into that which underlies in heavy strata throughout this region. The limestone blocks are blue or buff like the Devonian strata in color, though, locally, they are found in every degree of decomposition, so that in one place a complete series from fresh rock to iron concretion and red clay can be gathered. At Varco, below Austin, in quarries of the Austin Cement Works, a preglacial channel about ten feet deep in the Devonian limestone is well shown, and in it the rock surface is black stained and decomposed. Upon this surface is a somewhat disturbed, variegated clay, not in strata but coating the inclined surface. Reconstructed, the preglacial condition around Austin seems to have been simply that the Devonian limestone, blue in original color, passed upwards into buff of the same formation. This, twenty feet or more thick, was penetrated by clay-filled cracks at the top, or covered by a coating of black iron-manganese oxide, etc., from one to two inches thick; the former condition passing to a red clay with black concretions and decomposing brownish limestone blocks; the other phase, that of the black unbroken rock surface, as at Varco, passing simply into homogeneous residuary clay. The pea-green clay is calcareous and it was not residuary but formed strata or laminæ between the limestones. Such a clay is seen in the Devonian at Le Roy, in the southeastern part of the county,[1] and again it should not be forgotten that the Devonian at Austin extends upwards nearly to the horizon of the Rockford shales, so well developed southward in Iowa.

The identification of the clays at Austin as Cretaceous was based upon a few specimens of fossil leaves found in digging a well (*vide op. cit.* p. 354). At first the subjacent limestone was also called Cretaceous by N. H. Winchell, but this mistake was

[1] See also Geol. Surv. Minn., Vol. I, p. 357, l. 7.

soon corrected through the identification of fossils by H. S. Williams. The occurrence of a true Cretaceous fossil in this Pleistocene deposit does not prove the origin of the clays, because also pre-Cambrian rocks and Devonian fossils are scattered quite abundantly in it. The Austin clays are not Cretaceous and it is very doubtful that they ever could have been such.

Another supposed Cretaceous deposit has been described, also by N. H. Winchell in the northeastern part of Mower county. There is, in this district, a "white pebbly conglomerate which passes into a ferruginous grit." In the adjacent part of Fillmore county, the same occurs, and was identified as Cretaceous. Near Spring Valley, a few miles farther south, a blue clay is said to represent the Cretaceous. No actual outcrops were known of strata *in situ*, and one might not now refer any of these to the Cretaceous, especially since the "Austin rock" is now known to belong to a different formation. Indeed, they were so referred only with doubt by Professor Winchell. Of course, Cretaceous as well as Devonian, Ordovician, Cambrian and older rock débris might be found commingled in the Pleistocene drift.

In Goodhue county, about sixty miles northward from Austin and ninety east of New Ulm, there is another deposit consisting of interstratified clay and sand, which is described by N. H. Winchell as Cretaceous.[1] Fossil leaves have been found in the sandstone and are identified by Leo Lesquereaux as Cretaceous fossils.[2] I have verified the occurrence of the leaf imprints, though of course their identification is not questioned. The fossils belong to the same age as the strata and the latter are therefore of Cretaceous origin since the former are.

Before describing this patch of sand and clay, it may be recalled that the deposit lies beyond the limits of Wisconsin and Iowan drift in the region of loess and Kansan or pre-Kansan drift. It is in an undulating prairie bordering on the deep valleys which lead to the Mississippi valley about twelve miles

[1] Op. cit., Vol. II, p. 43.

[2] They are described in Final Rep., Vol. III, Minn. Geol. Surv.

distant toward the northeast. The Cretaceous lies on one of the higher hills of the prairie. It is covered by the loess five to ten feet thick, which also covers the Kansan eskers, the Saint Peter sandstone of the butte-like hills and, at lower levels, the Shakopee dolomite hills, and then, on the steep sides of the valleys, the Oneota dolomite and Jordan sandstone. The glacial till or gravel is spread beneath the loess, over the same Cretaceous, Ordovician and Cambrian formations. Under this drift, the dolomite formations are commonly protected by a dark-colored residuary clay, containing chert and iron concretions. Two or three miles to the westward from the Cretaceous patch, the Saint Peter sandstone is conformably overlaid by the Galena (Trenton), and upon that may once have rested the Maquoketa (Hudson) strata. Now at the particular locality where the Cretaceous patch occurs, there is neither Galena nor Maquoketa extant, but the Cretaceous rests upon the Saint Peter sandstone or possibly in part upon the Shakopee dolomite. Further, it is evident, as shown by N. H. Winchell (*op. cit.*) and others, that all the geologic formations, from the Galena down to and below the Jordan sandstone, were once, in this region at least, uniform, coextensive, sedimentary deposits, and that all the valleys are due to later erosion. This valley cutting was accomplished before the glacial deposits were spread on them. The erosion of the loess and glacial till and gravels now going on is very slight as compared to that which produced the valleys over which those deposits have since been spread.

The Cretaceous strata lie where erosion had already obtained. The Galena series, at least, must have been eroded away before Cretaceous deposit could be laid upon Saint Peter sandstone. Again, the valleys on either side of this Cretaceous, as we now see it, must be younger than such a sedimentary formation if the same is *in situ*, else the formation should lie in the valley and not on a hill. This Cretaceous patch, like the hills of Saint Peter sandstone and of other older formations in the same locality, must be the outlier or eroded remnant of a once more extensive sedimentary deposit; unless, like the bowlders of

granite, the gravels and the till, it was transported by the glacier *en masse* from the northwest.

The Cretaceous in Goodhue county is known to cover about one-half square mile from 0 to 40 feet deep. It lies in sections 3 and 10, town of Goodhue, three miles northward from Goodhue village, and one and one-half miles east of Clay Bank station. It consists of a succession of sand and clay strata which are now quite irregular, although when deposited they could not have been so. The top of the mass always shows disturbance from a glacier which has moved over it, although comparatively lightly, from a northwesterly direction. In the many pits which form a long series of exposures, no stratum appeared undisturbed, but rather every one has been shifted on the other. "The thickness of the parts varies in short distances, some of the beds tapering to points and wholly disappearing."[1]

It should be emphasized, that the irregularities of the twenty or more successively alternating sand and clay strata, are not due to sedimentation as believed heretofore, but to later dislocation which was evidently glacial. In the most regular sequence observed, which is seen in a pit on the west side of the highway, every stratum has been shifted upon the other. In other exposures they show even more irregularities, and it is quite impracticable to describe all the peculiarities of this kind. But all of them are modifications of a once regular series of alternating clay and sand strata which, as is shown by their continuity in some cases, were probably very uniform and continuous when deposited as sediment. In one case a fairly regular succession now forms a syncline. The strata dip on the one side at an angle of fifteen degrees for forty feet at least. The other side is steeper and shorter. One coarse sandstone stratum in particular runs uniformly two feet thick down one side and up the other. It could not have been so deposited. A clay stratum on the contrary is bunched into a lenticular mass in the syncline. It would not have been so deposited. Rather frequently a sand stratum is interrupted or widely isolated in thick lenticular

[1] WINCHELL, op. cit., p. 44, l. 6.

masses, then included in the clay. An exceptional case of dislocation is seen in one corner of the easternmost exposure. Here a mass of sand, eight to ten feet wide and exposed ten feet deep, interrupts the strata. Its median portion, vertically, shows obscure horizontal stratification. On the right and left, clay only, joins irregularly on the sand in large confused masses, which project in an irregular sheet two feet thick, over the same. Probably the clay extends under it. The adjacent sand strata are cut off or squeezed out abruptly by the clay, which surrounds the large sand mass. In composition this sand horse is coarser than any of the strata, but near by the same kind of coarse sand was found scattered loosely over the top, like drift. It is not ordinary glacial sand however.

Lamination is generally obscure. The clay is without lime and is decidedly tough and fine in texture. The sandstones are either nearly white and friable, or have been converted to a veritable crystallized iron ore in parts of the same stratum. It is in the dark red hard parts of the sand strata that the fossil leaf imprints occur. These parts of the strata have resisted distortion, being only here and there brecciated, so that character of stratification, like the fossils, may be clearly discerned. The rock alterations must have preceded the mechanical disturbance of the strata. Small pieces of mica further characterize the sand and coarser clays of the strata.

Excepting in the case described above, the strata are not jammed together but appear rather to have slid one on another. Even the top in contact with the glacial drift is not mixed with pebbles or bowlders, although it has been distorted to the depth of one to three feet by the glacier. The till, two feet thick or merely a thin covering of gravel, with here and there a large bowlder perched up into the loess instead of buried in the Cretaceous clay, overlies the whole mass.

What lies beneath the Cretaceous here is unfortunately not known, except in the southern part of the field, where an excavation for the railway passes through the Saint Peter sandstone. The top of exposed Saint Peter rises as high as that of

the Cretaceous. It is crusted over in one place with a black coating of iron. Upon it is found a few inches of unassorted fine sand like that of the Saint Peter sandstone, and numerous small bright pebbles, while in other places the loess rests upon it instead. On either side of the Saint Peter sandstone are Cretaceous strata which are now weathered, however, and their relation to the Saint Peter is no longer clearly defined in the exposure. But they seem to have conformed to the surface of the latter, without intervening deposit. The generally undulating arrangement of the strata in all the pits argues also that they conform to an irregular or undulating surface beneath them.

If the strata had been deposited just where they now lie, they would have been unconformable to the underlying structure, and horizontal instead of inclined. The strata have been disturbed if not transported *en masse*. Whether they have been moved a few feet or a few hundred miles remains to be shown. Likewise, one must define the mass as either in its originally deposited character, Cretaceous, or as now glacial drift. An elaborate discussion on how far rock must be moved out of location before it is to be called drift, would end in this case, however, only in the recognition of the fact that possibly some unexposed stratum may be still *in situ* as Cretaceous.

I endeavored to find some proof that this patch is an outlier of a once widespreading formation of this region. The striking presence of mica sand argues a general formation rather than a local one. In Cretaceous time, the only known source of mica must have been either granitoid rocks far to the northeast or to the northwest, or possibly the Saint Lawrence formation and Cambrian sandstones, the exposures of which could have been only far distant, while Cretaceous sediments were depositing three hundred feet above them in this region of nearly horizontal formations. Moreover I did not find that the Saint Peter sandstone detritus forms any part of this Cretaceous rock. Yet, the Saint Peter stands adjacent and protrudes to the height of the other deposit. The materials are evidently from distant sources. In the vicinity of this particular hill are other hills or

buttes which must be equally high, because they cut off the view of the more distant horizon. On these hills are farmhouses, with the never-failing wells two hundred feet deep. Excavations for cellars have also been made, but although the value of the "Clay Bank" must inevitably have been impressed upon every mind in the neighborhood, still no one is known to have observed similar clays or equivalent deposits on other hills. It is very probable that they do not exist.

In view of this contradictory evidence, other hypotheses were sought which might harmonize them. It may be suggested that either the deposit was that of a meandering river, or that the mass has been borne hither by the capricious glacier. To the former hypothesis there is the seeming objection, that the alternating strata of uniform composition and sharply defined stratification, do not suggest a river flood deposit, but it may explain the presence of mica in the sand. To the other hypothesis, however, no objection arises which cannot be circumvented.

The mass of clay and sand is large, and cannot be compared to any mass of granite or of limestone which are found among erratics; but the Galena (Trenton) shales which are tougher than limestones are known to have been transported *en masse* by the Wisconsin glaciers. Bodies of this kind are known within the city limits of St. Paul, Minnesota. One is at St. Anthony Park station, and although it is much distorted, is yet mainly unmixed with foreign materials and is highly fossiliferous, It is exposed in four places within half a square mile. At Dale and Martin streets, a similar body covering an acre and possibly a much larger area, lies in the drift high above the horizon of the shales *in situ* as exposed in the region. At Stickney, Curtice and Concord streets, a somewhat smaller mass has been cut through by the Chicago and Great Western railway, and this mass preserves the stratification quite completely although the strata form a syncline and an anticline and overlap the till. These masses, however, have necessarily been transported more than one half or one or two miles from where they were dislodged.

The Cretaceous near Goodhue is very much tougher than the

shaly clays of the Galena (Trenton) at St. Paul. The clay strata when wet would scarcely fracture under any conditions and the sand strata between them, being largely not compacted, could allow them more free movement and keep the mass from breaking apart, as long as the strata remained approximately horizontal or compressed. Moreover there is little instead of much gravel and till associated with it into which it might have been jammed by the glacier. The condition of the glacier at the time when this mass could have been dropped where it now lies, is indicated by a fine example of an esker which lies about one mile west of south, looking like one of the sandstone buttes or a dolomite swell. The esker presents an abrupt slope on its northwestern front, and extends indefinitely to the southeastward. At the foot of the esker is an exposure of Saint Peter sandstone. The brow of the hill has been excavated for a sand pit, and the strata of gravel may be seen in it dipping gently on all sides into the hill. Thin strata of nearly pure sand, unlike anything but Saint Peter sandstone, are conspicuous. The depth of the gravel is about forty feet, but the loess covering obscures the form of the hill and conceals the most of the esker deposit. A similar esker lies nearly two miles farther in the same direction, standing west of the village of Goodhue. The eskers and the Cretaceous lie in line, and notably they are perched on the brow of sandstone hills, fronting northwesterly. Again, the height of these eskers contrasts with the thinness of the till, which is only one or two feet thick, as seen in cuttings in the region. The glacier which strewed débris thinly, and which scarcely drove the residuary clays from the rock surfaces beneath it, must still have been a gigantic ice mass to have built such eskers on the farther side of a broad valley. A clay mass such as the Cretaceous here, would have been comparatively slight when once loaded upon the ice.

It is not my intention to urge this hypothesis of glacial transportation, but it is worthy of remark that the successive loose sand and tough clay strata would have been the best adapted of any to be easily slid upon the glacier, to be transported without

disruption, and to be laid down without dissolution. The peculiar rolling up of sand strata into lenticular masses between clay strata might not be easily produced by any single continued thrust of an overlying glacier, but might easily be the result of successive reverse sliding movements.

Very little, if any, attention has been paid to this Clay Bank by geologists since N. H. Winchell briefly described it, but it is not without scientific interest in its present significance, whether it is Cretaceous or Pleistocene. It has also a high commercial value. Professor Winchell believed that this clay and sand deposit might extend over several square miles and he has represented about sixteen sections on the map of Goodhue county (*op. cit.*). He has described a number of observed and reported Cretaceous exposures as occurring from two to fifteen miles distant, but none of these afford the desired evidence. Clays like that at Clay Bank might of course be expected to occur in other places in the drift and only the occurrence of strata unquestionably *in situ* can prove the same to have been deposited as Cretaceous, not as Pleistocene, in this region. There are also two other deposits which may be mistaken in this region for Cretaceous. One, the ferruginous conglomerates of the oldest drift, a sort of residuum of the oldest till, occurs here and there. No ferruginous conglomerate nor any gravels were observed in the strata of the Clay Bank, and indeed none are known to be from Cretaceous strata. A more deceptive deposit in this particular region is the variegated clays of the Shakopee formation. Such an exposure is seen one mile north of Clay Bank station in a railway cutting, where three or four feet of clay strata cover the side of a dolomite swell. When weathered, this clay remains long intact, while the dolomite strata above and beneath it are reduced. It might then be mistaken for a Cretaceous clay.

There are no Cretaceous deposits known in southeastern Minnesota which are unquestionably *in situ*, although Cretaceous clays, with fish teeth and bones or fossil leaves in sandstone, are not infrequently discovered in any of the "northwestern drift" in Minnesota. Their occurrence does not prove the proximity

of Cretaceous strata. Other supposed Cretaceous rocks are very evidently not such. With the exception perhaps of the half square mile in Goodhue county, no areas should be indicated on the map in southeastern Minnesota either as known or probable Cretaceous. At, or a little beyond, the western border of the region herein considered, the first Cretaceous begins, *i. e.*, near New Ulm.

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Minneapolis, Oct. 17, 1898.

THE SILURIAN FAUNA INTERPRETED ON THE EPICONTINENTAL BASIS.

THE oceanic movements which brought the Ordovician period to a close are believed to have been such as to affect all continents in a similar manner. The transition period from Ordovician to Silurian was probably characterized by a special shrinkage of the earth, due to an effort at adjustment to the stresses that had been accumulating during the whole of Cambrian and Ordovician time. In this shrinking process it is assumed that the ocean basins were made deeper and their capacity increased so that the waters of the shallow seas lying upon the borders of the continents and reaching into their interiors to some notable extent, were drawn off, and the bottoms of these seas became a part of the dry land. It is assumed that the continental shore lines migrated oceanward until they no longer lay upon the continental platforms themselves, but upon their abysmal slopes, and the former broad, shallow-water tracts of the sea-shelves were reduced to narrow bands. With the destruction of these shallow seas upon the continental platforms, the multitudes of shallow-water organisms which had existed in them were largely forced into extinction.[1]

After the readjustment of the solid earth, the seas began again gradually to creep upon the continental platforms by means of the landward cutting of the sea-cliffs, by reason of the sediments carried down from the land and dumped into the ocean basins, and by reason of the gradual settling back of those portions of the crust which had been locally forced upward beyond isostatic equilibrium. With the continuation of these processes new sea-shelves and new epicontinental seas came into

[1] For a fuller exposition of this hypothesis see "The Ulterior Basis of Time Divisions and the Classification of Geologic History," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 449.

existence, and grew in extent as the period advanced. These were the Silurian seas, and in them there evolved a new assemblage of shallow-water organisms, the Silurian fauna. This fauna was derived genetically from those remnants of the earlier Ordovician fauna which had happened to survive in favored localities, but with the very general expansion of the shallow waters, a great expansional evolution took place and many organic characteristics, showing a notable advance in differentiation beyond that of Ordovician time, came into existence and were characteristic of Silurian time.[1]

As the Ordovician waters were gradually drawn off from the continental platform, the once broad sea, extending from eastern Canada to beyond the present Rocky Mountains, with its wealth of organic life, was gradually contracted, and its life either gradually became extinct or was forced into modified forms or compelled to emigrate under unfavorable conditions. The remains of the last survivors, of this once magnificent fauna, within this area, are now found in the lower beds of the Medina formation in Virginia.[2] With the passing of these last survivors, the interior Medina basin became a lifeless tract so far as any evidence has been left to us, save for some low types of aquatic plants and a few worm burrows. It was probably an isolated basin.

With the encroachment of the Silurian sea upon the continent, a junction was at last effected with the Medina basin, and again marine conditions, and a marine fauna occupied the area.

The Medina fauna of New York,[3] which has been described from the upper beds of the formation, signals the return of the marine conditions. This fauna is a meager one containing but thirteen species, most of which would not be out of place in either an Ordovician or a Silurian fauna, but the presence of a

[1] See "A Systematic source of Evolution of Provincial Faunas," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 597.

[2] STEVENSON, Proc. Am. Phil. Soc., Vol. XXII, pp. 142 and 150; Vol. XXIV, pp. 85, 87 and 94.

[3] Pal. N. Y., Vol. II.

species of the brachiopod genus *Whitfieldella* stamps the fauna as of Silurian age.

In the New York section, which is usually taken as the standard for our continent, the Medina formations constitute the lowest division of the Silurian system. The Clinton division following the Medina consists in New York of a series of strata diverse in character. There are beds of shale, sandstone and limestone, and one very persistent stratum is the fossil iron ore bed. This division was well named "Protean Group" by the early New York geologists. The characters of the strata are precisely such as one would expect to find in a series of beds deposited during a period of readjustment of local conditions.

The Niagara division of the Silurian, following the Clinton, essentially represents the period when local conditions had become readjusted and equilibrium established. It was primarily a limestone-forming period, and although the Niagara shales of New York are classed with the limestone, it would perhaps be more natural from a stratigraphic point of view to place them in the preceding division.

From the point of view here taken, it will be seen that the Clinton and Niagara cannot be considered as separate and distinct time divisions having the same significance throughout the entire area in America which was originally covered by Silurian waters. The two divisions, rather, exemplify two sets of conditions. In the Mississippi valley the Clinton period of readjustment was short, and is represented by a very thin series of sediments. The conditions of equilibrium, with clear limestone-depositing seas, very soon became established after the incursion of the Silurian waters, but in New York, in the region nearer the finally established shore line, this period of readjustment occupied a much longer time. In the southern Appalachian region the Niagara conditions seem never to have been attained. Indeed, since it was probably the last region reached by the encroaching sea, it is possible that even the Clinton conditions did not begin there until long after the Niagara conditions had become established in some other parts of the continent. Taken

in a time sense, the Clinton and Niagara divisions of the Silurian must be considered as a unit, the stratigraphic distinctions between the two being of but local significance.

In like manner the Clinton and Niagara faunas must be considered as a unit. To be sure there are species which in any given area are known only in the Clinton strata, and others which are restricted to the Niagara limestones; there are also species restricted to a single stratum of either one division or the other. From the very nature of the case this would be expected, because all organisms are not so constituted as to be able to adjust themselves to all conditions of environment. There are always sure to be local adaptations in any general fauna, to the varying local conditions both in time and space. And so we must look upon the general Silurian fauna of America, not as constituted of two sharply defined faunal divisions, the Clinton and the Niagara, but as being one composite faunal unit composed of numerous faunulæ, adjusted to a great variety of local environments.

The same general Silurian fauna which occupied so large a portion of the North American continent, also was present in other parts of the world. In Europe it is recognized with its local adaptations in England, in the island of Gotland, in Russia, in Bohemia and elsewhere. Many species are common to the Silurian beds of England and North America, and there are like relations between the faunas in America and other parts of Europe. In other parts of the world this same general fauna has been found. As far away as New Zealand,[1] a Silurian fauna has been studied, in which there are several species common to Europe and North America. These facts show that there must have been intercommunication between the Silurian seas of different parts of the world, and means of intermigration for the organisms which inhabited them.

Although it has long been recognized that some means of intercommunication between Europe and the interior of North America must have existed during Silurian time, the pathway

[1] Quart. Journ Geol. Soc. Lond., Vol. XLI, p. 199 (1885).

connecting the two regions has never been definitely located. During Ordovician time there was an open passageway through the St. Lawrence valley joining the interior epicontinental sea with the ancient Atlantic Ocean, but during the Ordovico-Silurian transition period, the Taconic range of mountains was elevated, and this passage entirely closed. The Appalachian land was the eastern barrier to the interior Silurian sea, and during this period this land was joined to the Laurentian land at the north. East of this land barrier the Silurian fauna occurs in the eastern provinces of Canada, but these eastern strata are not continuous with those in New York, and the communication between the two regions was not direct.

In a southern direction the Silurian strata thin out and become more clastic in constitution, indicating proximity to a shore line, and it is probable that even at this early period the western extension of the Appalachian land, described by Griswold [1] and Branner [2] was already in existence.

The western extension of Silurian strata cannot be definitely shown, but they are nowhere a conspicuous feature in the United States further west than Iowa. Beds in the far West containing the chain coral, *Halysites*, have been referred to this period, but usually upon insufficient evidence, for this genus is known also to occur in the Ordovician. In those rare instances where other forms have been found associated with the chain coral, they usually have been of an Ordovician rather than a Silurian facies. Nowhere in the great western region has the wonderfully prolific Silurian fauna of the East been found, and it is safe to assume that the greater part of this region was above sea level during Silurian time.

This leaves the North as the only available outlet for the interior Silurian epicontinental sea. A glance at the accompanying map (Fig. 1) indicating the distribution of the Silurian outcrops in North America, shows their northward extension. There is an extensive area in the region of Lake Winnipeg (XIII), one

[1] Proc. Bost. Soc. Nat. Hist., Vol. XXVI, p. 474.

[2] Am. Jour. Sci. (4), Vol. IV, p. 357.

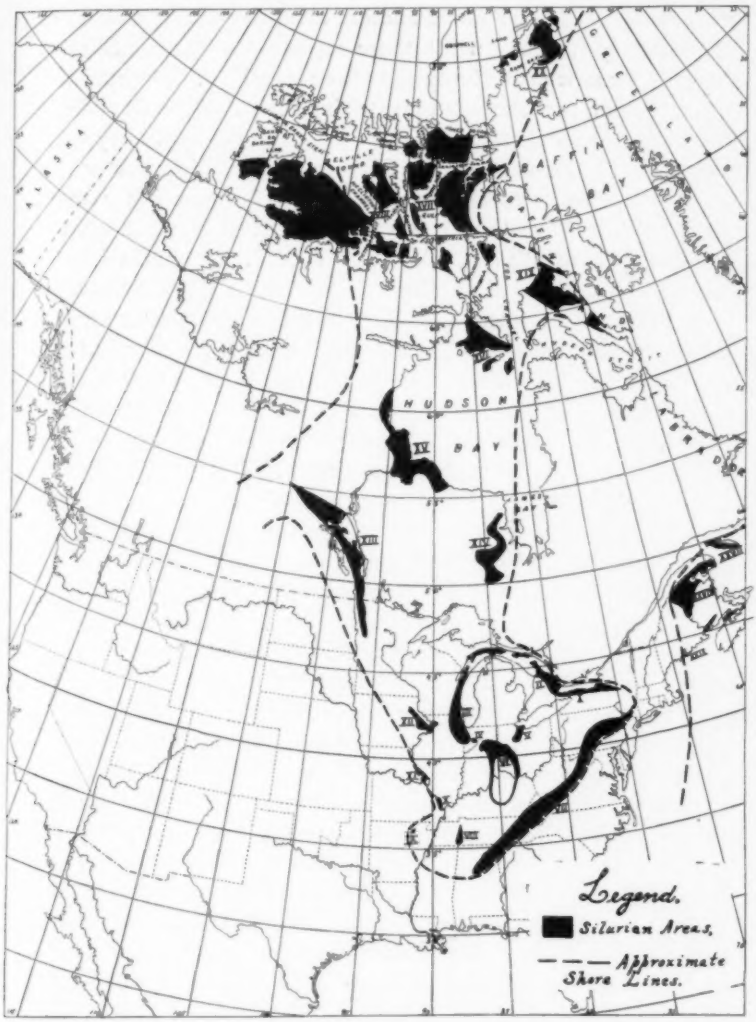

FIG. 1. Outline map of North America showing the position of Silurian outcrops and the hypothetical shore line of the Silurian epicontinental sea. The dark areas represent the Silurian outcrops, except in such instances as are specifically explained in the text.

near James Bay (XIV), and another along the western shore of Hudson Bay (XV). In all these regions the general Silurian fauna of America and Europe has been identified. The strata lie directly upon pre-Cambrian crystalline rocks, and as they could not have been deposited in these isolated patches, they must represent the remnants of a Silurian sheet which was at one time continuous and covered the entire intermediate region. Silurian strata have been recognized still further north on the islands at the mouth of Hudson Bay (XVI), and on the islands and mainland round about the Gulf of Boothia (XVII) and west of the Boothia peninsula (XVIII). In these two latter regions Silurian fossils have been found in abundance by several of the Arctic expeditions. From this general area Dawson[1] gives a list of thirteen localities from which Silurian fossils have been collected. If the region could be visited and properly studied, a prolific fauna would doubtless be secured. West of McClintook Channel the Silurian has not been properly differentiated from the Devonian, and Silurian fossils have not yet been found. In northern Greenland and in Grinnell Land (XX) Silurian strata with their characteristic fauna are known to exist.

Turning now to the map of the north polar regions (Fig. 2), it will be seen that the distance between northern Greenland (XX) and northern Russia (XXIII) where the Silurian fauna is known, is not extreme. At very near the halfway point between, lies Spitzbergen (XXI). The shores of these islands are known to consist for the most part of Palæozoic strata, and, although no Silurian rocks have yet been recorded from the islands, the presence of the Palæozoic strata is a connecting link across this little known Arctic region. In western Russia (XXIV) the Silurian strata are not exposed, but the area colored is occupied by Palæozoic strata of younger age than the Silurian, and is possibly underlain by the Silurian. The area in Russia between the regions marked (XXIII) and (XXIV) is occupied by Mesozoic strata, and the Palæozoic beds with the Silurian among them, doubtless underlie the whole region. The island of Gotland in

[1] Ann. Rep. Geol. Surv. Canada, new series, Vol. II, p. 45 R. (1887).

the Baltic (XXV) is constituted entirely of Silurian rocks, and one of the most prolific Silurian faunas known to exist in so small an area has been described from here.

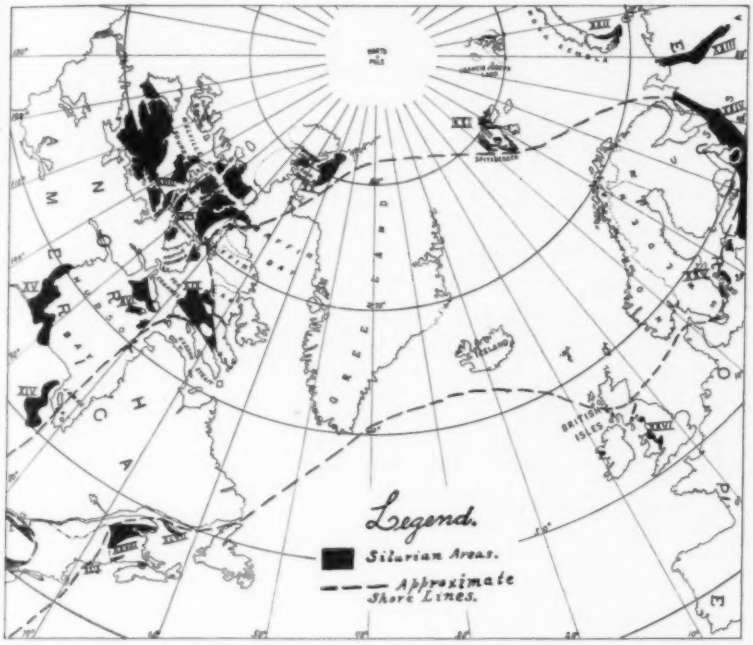

FIG. 2. Outline map of the North Polar regions with the Silurian outcrops and the hypothetical Silurian shore lines indicated.

The distributional evidence of the Silurian strata favorable to the existence of a north polar connection between the Silurian seas of Europe and those of the interior of North America having been pointed out, let us turn to the evidence of such a connection which may be afforded by the life of the period. A study of the Silurian faunas in the Mississippi valley, shows some remarkable points of resemblance with the faunas of north-

ern Europe, which are lacking in a comparison of the New York and the European Silurian faunas.

In the fauna of this age at Chicago and in northern Illinois, some remarkable forms of crinoids have been recognized which have not hitherto been recorded from America. One of these is *Crotalocrinus*, one of the most highly specialized genera of crinoids that has ever been described. Its arms, instead of being simply branched, as is usually the case, have the subdivisions joined laterally in such a manner as to form great, flat, flexible extensions from the body. It has been found most abundantly upon the island of Gotland, but it also occurs at Dudley, England, and is now found in the Chicago fauna. Two genera, *Corymbocrinus* and *Pycnosaccus*, founded upon Gotland specimens, are now found for the first time in America in the Chicago fauna. The first of these also occurs in England, but the second has been previously recognized only in Gotland.

Petalocrinus is another highly specialized crinoid genus with the arm branches from each ray consolidated into a triangular plate or "arm fan," so that the creature with its arms extended closely resembles the corolla of a flower with five petals. This peculiar genus was first described by Weller[1] from Iowa, and later a specimen was found from Indiana. The genus is now known to occur in Gotland, and several species have been described from there by Bather.[2]

Turning to the corals we find that the peculiar and highly specialized genus *Goniophyllum*, a quadrangular cup coral with an operculum of four triangular plates is found in England, Gotland and Iowa,[3] but is recognized nowhere else. The peculiar little twisted brachiopod, *Streptis*, known both from England and the continent of Europe, has more recently been recorded from the Silurian near Batesville, Ark.[4]

Now the presence of all these peculiar and highly specialized forms in various localities in the Mississippi valley and in

[1] Jour. Geol., Vol. IV, p. 167.
[2] Quart. Jour. Geol. Soc. Lond., Vol. LIV, p. 401.
[3] Jour. Geol., Vol. IV, p. 170.
[4] Am. Jour. Sci. (3), Vol. XLVIII, p. 329.

Europe, and their entire absence from New York where the fauna has really been more carefully studied than in any other part of America, is, to say the least, suggestive. If there had been a direct east and west pathway of communication between Europe and the interior of North America, why have not some of these forms also been found in New York, an intermediate locality which would have been in the direct path?

Only a few of the more remarkable forms common to the Mississippi valley and northern Europe, but absent from New York, have been mentioned. There are many others in various classes, of a more modest and ordinary appearance, which need not be specifically mentioned here. The trilobites of the Chicago fauna, however, when properly studied, bid fair to bring out fully as remarkable points of relationship between the two faunas as the forms already mentioned.

The facts of the distribution of the life indicate clearly that northern Europe was more closely associated with the Mississippi valley than with the New York region in Silurian time. The sea-shelf connection must have been in either a southern, western, or northern direction from the interior of America. If it is shown that the Appalachian land extended westward across the southern part of the United States in Silurian time, the southern route is barred, but if that land was not present the pathway of intermigration would have been around the southern end of Appalachia and then north along its eastern shore and across to Europe. According to the mode of interpretation here adopted, it should have been, under these circumstances, along the sea-shelf of the north Atlantic, except as the species were adapted to pelagic migration, and as the Silurian strata in the eastern provinces of Canada lie in this path, some of the peculiar forms mentioned might be looked for in their fauna, but they are entirely absent so far as known. However, the stratigraphic evidence seems to shut off this southern route, because the Silurian strata grow thin in that direction and become more clastic, exhibiting every evidence of having been deposited near a shore line.

The western route need not be considered, because the Silurian fauna is not known to have any notable development in that direction. This leaves only the northern route. The presence in the Arctic localities of some of the peculiar genera already mentioned, would furnish the most substantial evidence in favor of this route. The conditions under which fossils have been collected in the Arctic regions have been such, however, that the fossil faunas of the far north are but poorly known. Although this is the fact, the genus *Crotalocrinus* has been identified from a small island in Wellington channel[1] from specimens of the stem alone. The stem of this genus, however, is quite distinctive, and the identification is probably correct. The other forms mentioned have not yet been found there, but they probably will be if the proper opportunity for the study of those faunas is ever offered.

If the interpretation here offered be the correct one, then the usual conception of the Silurian geography of North America must be somewhat altered. We must conceive of a North Polar sea with a great tongue stretching southward through Hudson Bay to about latitude 33°. There were doubtless islands standing above sea level within this great epicontinental sea, and at the latitude of New York there was a bay reaching to the eastward in which the Silurian sediments of the New York system were deposited. There may also have been a secondary tongue reaching southwestward from some point in Canada, into the Rocky Mountain region. Labrador, Greenland, and Scandinavia were in a measure joined into one great land area, though perhaps with its continuity broken, with a sea-shelf lying to the north of it and another to the south. Another epicontinental tongue of this northern sea extended south into Europe, bending to the west around the southern part of the Scandinavian land and connecting with a Silurian Atlantic Ocean. The sea-shelf to the north of the Labrador-Scandinavian land was a means of intercommunication between northern Europe and the interior of North America, and the sea-shelf to the south

[1] Quart. Jour. Geol. Soc. Lond., Vol. IX, p. 315 (1853).

of this land was a pathway between England and eastern Canada. Other tongues reaching to the south were probably present through Asia and through the Pacific Ocean, the New Zealand communication coming through one of these.

This interpretation of the Silurian, and similar interpretations of the other geologic periods, seem to call in question the generally accepted theory of the exogenous growth of the North American continent, and seem rather to point to an endogenous process of growth.

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BYSMALITHS.

A LACCOLITH as defined by Gilbert[1] is a body of igneous rock which has forced itself by intrusion, in a molten condition, between strata of sedimentary rocks in such a manner as to have lifted the overlying strata in a dome-shaped arch above it. The arching strata may be stretched and cracked to variable degrees and the molten magma may penetrate them to a greater or less extent according to the character of the rocks and the amount of cracking. A symmetrical dome may be the ideal form of a laccolith, but as Cross[2] has shown is rarely assumed because of the many modifying conditions attending the process. The principal ones are: a position of the plane of fracture along which intrusion takes place oblique to the bedding of the strata; lines of structural weakness in the strata; the presence of earlier intrusive bodies; the lack of coherence and of pronounced bedding in the strata invaded. Gilbert's use of the term laccolith embraced all lenticular bodies of igneous, intrusive rock occurring in stratified sedimentary rocks.

A laccolith is to be distinguished from an intrusive sheet of igneous rock, which also has been in most cases intruded between strata that were more or less horizontal at the time and required to be lifted by the force within the molten magma. The difference lies in the thickening of the igneous body into a more or less lenticular mass in the case of the laccolith, and in its retaining an almost uniform thickness in that of a sheet. In both cases the act of lifting the superincumbent strata must have been due to the same kind of force, namely, that exerted by a liquid under pressure upon the sides of a containing reser-

[1] GILBERT, G. K., Report on the geology of the Henry Mountains, U. S. Geog. and Geol. Surv. of the Rocky Mountain region, J. W. POWELL in charge. Washington, 1877.

[2] CROSS, W., The Laccolithic Mountain Groups of Colorado, Utah, and Arizona. 14th Ann. Rep. of the Director of the U. S. Geol. Surv., pp. 236. Washington, 1895.

voir. The difference in the results must be occasioned either by differences in the direction and rate of the intrusion, or by variations in the resistance offered by the overlying rocks. A sudden vertical thrust may lead to the arching of the strata immediately above its point of application. Local weakness of the strata may cause their elevation in particular places, as remarked by Cross. Another cause undoubtedly lies in the initial arching of strata brought about by other dynamic forces tending to bend and dislocate rocks. Such movements may be accompanied by extravasation of molten magmas which will follow planes of weakness in the dislocated rocks and will force themselves most readily where the rocks offer least resistance to displacement.

There is nothing in the petrographical characters of the rocks of intruded sheets and laccoliths in general to indicate any physical difference in the molten magmas from which each may have been formed. In both instances the magmas may have been equally liquid at the time of intrusion, or may have had similar compositions.

As regards their shape, it may also be noted that in sheets the lateral dimensions are very great in comparison with their thickness, whereas in laccoliths the thickness is much nearer the lateral dimensions.

Cross has shown that a certain amount of vertical displacement of the overlying strata may accompany their arching without changing the general character of the intruded body as in the laccolith of Mount Marcellina in West Elk Mountains, Colorado.[1] But, when vertical displacement with faulting is one of the chief characteristics of the intrusion, a distinction from normal laccolithic intrusion should be recognized. In the extreme this would result in the forcing upward of a more or less circular cone or cylinder of rock, which might be driven out at the surface of the earth, not necessarily in a coherent condition, or might be arrested at any stage of such extrusion and so might terminate in a dome of strata resembling the dome over a lacco-

[1] Loc. cit., pp. 182 and 236.

lith. By this mode of intrusion, the vertical dimension of the intruded mass becomes still greater as compared with the lateral dimensions, so that its shape is more that of a plug or core. Such an intruded plug of igneous rock may be termed a *bysmalith* (*βύσμα* = plug, *λίθος* = stone). There is then a transition from a flat, intrusive sheet to a laccolith with lenticular form, and from this to a bysmalith with much greater depth and considerable vertical displacement.

The resemblance of a bysmalith to a stock of igneous rock is such as to suggest at first their identity or close relationship. And though bodies of igneous rock may occur whose character might lead to their being classed with either of these types of intrusion, nevertheless it will be found advantageous to discriminate between bysmalith and stock by limiting the term stock to such bodies as occupy nearly vertical tubes or funnels of indefinite depth in rocks of any and all kinds, massive, schistose or stratified, and which maintain such a relation to them as to appear to belong to the category of dikes. Such tubes or funnels have been produced most probably by the enlargement of a fissure or a cluster of fissures by the carrying up of fragments torn from the walls. Stocks frequently represent the filling of a channel through which successive eruptions of magma have passed, as the conduit of a volcano. The formation of a bysmalith is more properly one act of eruption, and the solid rock removed is a block of nearly horizontal strata lifted at one time.

Examples of bysmaliths have not been described as such to any extent so far as the writer knows. Russell[1] has called attention to what he considers volcanic plugs in the region of the Blacks Hills of South Dakota and has suggested their recognition as types of intrusions different from laccoliths. But in his description of them he has mentioned nothing that demonstrates or even indicates that they possess the character of a plug. In each case they may be central remnants of small laccoliths. This is made probable by the position of the prismatic columns, which would be vertical in the central part of a laccolith, whereas

[1] RUSSELL, I. C., JOUR. GEOL., Vol. IV, p. 23.

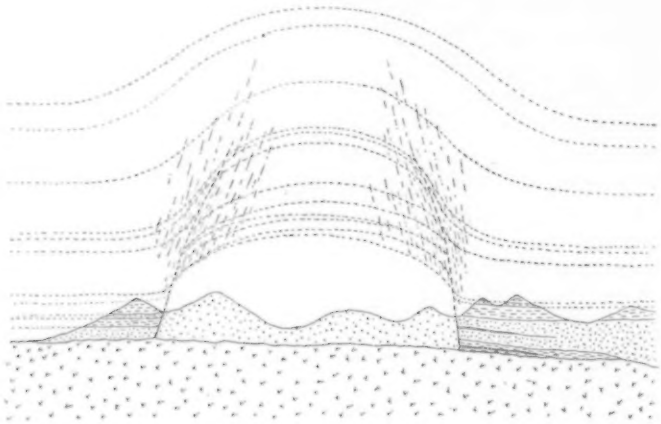
they should be horizontal in the body of a volcanic plug, and only vertical in the central part of its summit. In the case of Inyan Kara, mentioned by Russell, the dip of the limestone in the encircling wall, taken in connection with the diameter of the circle and the elevation of the igneous rock, is just what it might have been, had the igneous mass been a laccolith. The occurrences mentioned by Russell cannot be considered as illustrations of volcanic plugs without further evidence of their relations to the surrounding rocks.

In the Yellowstone National Park[1] at the southern end of the Gallatin Mountains, a great body of dacite-porphyry, three miles long and two miles wide, forms Mount Holmes and a group of mountains at the head of Indian Creek. In vertical extent the exposure of this mass is in all 2300 feet and throughout the exposure the character of the rock is so uniform as to indicate its being one mass solidified at one time.

Three quarters of the circumference of this igneous mass is in contact with stratified rocks, whose general position is nearly horizontal, but which in the immediate vicinity of the intruded body are bent abruptly upward, dipping away from it at steep angles. In several places the character of the contact plane is well shown, especially on the south side of the Dome, where a nearly vertical contact can be traced for almost a thousand feet. In each case the contact plane is almost vertical, inclining away from the intruded mass. From this mass small veins of igneous rock have penetrated the adjacent stratified rocks. The latter contained a large intruded body of andesite-porphyry in the form of a laccolith when the magma of the dacite-porphyry was intruded. The western boundary of the Holmes mass lies against gneiss and along a fault plane. An opening on this fault plane was probably the conduit through which the molten magma rose, for similar rock occurs along this fault line three miles to the north. While we have at present no knowledge of the configu-

[1] Geologic Atlas of the United States, Yellowstone National Park Folio, Areal Geology, Gallatin Sheet, Washington, 1896. See also the forthcoming monograph 32 of the U. S. Geological Survey on the Geology of the Yellowstone National Park chap. i.

ration of the bottom of the igneous mass, it seems quite probable that the magma spread in the shaly beds at the base of the Cambrian strata immediately over the nearly horizontal surface of the gneiss and beneath the laccolith already mentioned. The



Ideal section of the Holmes bysmalith.

thickening of the laccolith to the north and its contact with gneiss to the east may have hindered the further spreading of the later magma, resulting in a rupture of the overlying rocks in a block which was lifted by the intruding magma. The area of the block was more than five square miles and the vertical displacement more than 2000 feet, probably more than twice that height. Owing to the nearly uniform, crystalline character of the rock constituting the Holmes bysmalith, the grain being larger than that of the rock of the adjoining laccolith, there is little doubt that it solidified beneath a covering of strata. The slope of the planes of contact indicate that the intruded body possessed a steep dome shape, and the nearly horizontal position of the surrounding sedimentary rocks, at a little distance from the igneous body, prove that the arching of the strata took place at

a much higher horizon in the sedimentary terrane. The total thickness of beds, that were most probably superimposed on the gneiss at the time of the eruption under discussion, is about 9000 feet. These were lifted more than 2300 feet, possibly 4000 feet, and the position of the strata after the intrusion may have been similar to that shown in the accompanying figure, which corresponds in scale to the Holmes bysmalith. The section passes through Mount Holmes and Echo Peak, and does not intersect the conduit.

A more complex body of igneous rock closely related to a bysmalith occurs six miles farther north in the Gallatin Mountains at Gray Peak. It has broken across the strata and has forced into them numerous sheets of igneous rock. It is exposed at a much higher horizon than the Holmes bysmalith, cutting the Dakota conglomerate of the Cretaceous. Its position with regard to adjoining strata is not so well shown as in the case first described, however enough is exposed to prove its plug-like character.

It is probable that this type of intrusion will not be found to be as frequent as the laccolith, just as the latter is much less common than the intruded sheet.

The term *bathylith* has been proposed by Suess[1] for an intruded body having a more or less lenticular shape, which he considered to have been formed by intrusion of molten magma into a previously existing cavity made by the crumpling of the earth's crust. But, as Zirkel[2] has pointed out, the only difference between the bathylith of Suess and the laccolith of Gilbert lies in their mode of formation, their shapes being similar. It is questionable whether bathyliths defined in this strict manner exist. Indeed they probably do not. There has been a tendency among American geologists to use the term bathylith in a different sense from that in which Suess originally used it. This has been expressed by Dana[3] in his *Manual of Geology* in discussing the

[1] SUESS, E., Das Antlitz der Erde. Vienna, 1892, p. 219.

[2] ZIRKEL, F., Lehrbuch der Petrographie. Leipzig, Vol. I, p. 548.

[3] DANA, J. D., Manual of Geology, Fourth Edition, 1895, p. 811.

"granite-core" of the Sierra Nevada, California. "Such a mass of crystalline rock having irregular or indefinite outline has received the name of bathylith." This resembles the definition of stock given by Zirkel,[1] namely "stocks are irregular masses of considerable dimensions which, traversing the adjacent rocks without regard to their position, occur both in the stratified and massive terranes." However, it seems desirable to limit *stock* in the manner already suggested.

There is need for some general term that may be applied to large bodies of intruded rock whose exact character may not be evident, whose lateral extension may be quite irregular and whose depth may be profound. For such indefinite bodies the term bathylith may well be employed.

JOSEPH P. IDDINGS.

[1] Loc. cit., p. 544.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

III. REPTILIA—(*Continued*).

ICTHYOSAURIA.

The *Icthyosauria* or *Icthyopterygia* were large marine reptiles fish-like in their external appearance, with the body and limbs modified to serve the purposes of the animal in its aquatic life. The head terminated in front in a long and powerful snout armed in most cases with sharp conical teeth set in a single common groove which bordered the jaws. The skull was flattened above and the eyes were large and protected by a ring of bony plates, the sclerotic plates. The body was naked or covered with fine scales that are never preserved in the fossil forms. The vertebræ of the tail were abruptly bent downward at the extremity. This is very peculiar because in most fossil forms in which the bending of the tail occurs, the bend is upward. The external form of the tail was as in the modern fishes. There was a dorsal fin as in the fishes and the limbs were converted into paddles with a large number of phalanges.

The *Icthyosauria* were long considered as the most primitive of the reptiles because of the general appearance of the body which is so fish-like and because the paddles were considered as the direct modification of the fish fin. The bones of the upper arm and leg are so short and the carpal and the tarsal bones are so simple, being mere disks of bone, that they were regarded as the first steps from the basal segments of the fin, while the numerous phalanges were regarded as the segments of the fin rays. Now, however, there is every reason to regard the *Icthyosauria* as the specialized descendants of land-living forms.

The degeneration of the limbs and the phalanges is exactly the same as took place in the mammals that have become aquatic in their habits; the seals, walruses and the whales.

The *Icthyosauria* are known only from the marine rocks of the Mesozoic time and chiefly from the Liassic division. Specimens are known from North America, Europe and England; Queensland, Australia; New Zealand and the East Indies.

Mixosaurus, from the Triassic of Besamo in Italy, is one of the oldest as well as one of the most important of the group. The animal was small, about three feet long, the head was proportionately long and there were few teeth; the legs were long and well developed, typically those of a land-living form.

Icthyosaurus.—This genus contained a very large number of species; it is generally divided into two groups, the *Longipinnati* and the *Latipinnati*, accordingly as the limbs, which in the whole genus have been reduced to the condition of paddles, are long and slender with few, five or less digits, or broad and short with more than five digits. Typical of the first division are: *I. quadricissus*, *I. tricissus*, *I. tenuirostris*, *I. longifrons*, etc.; of the second group, *I. communis*, *I. trigonus*, *I. leptospondylus*, etc.

The genus is found most commonly in the rocks of the Lias. From the Wellendolomite of the Black Forest and the Muschelkalk of Crailsheim of Wurtemberg comes one of the oldest as well as one of the largest of the genus, *I. atavus*, about thirty feet long. From the Trias of Spitzbergen have been collected two species, *I. polaris* and *I. Nordenskioldi;* the first was very large, while the second was much smaller. From the Lias of England come the best preserved specimens that we have. Especially is this true of the Lyme-Regis region of Dorsetshire. *I. communis* from this region belongs to the first division, the *Latipinnati;* it was one of the largest of the genus. To the same division belong from this region: *I. intermedius* and *I. breviceps;* to the second class, among others: *I. platyodon* and *I. tenuirostris*. The first was a giant even among these large forms, but the second was quite small and delicate in structure. The paddles

had only three digits or rows of phalanges. The skull was very long and slender and the jaws were slender and curved. The whole animal was about twelve feet long.

The continental forms come almost entirely from the Upper Lias, the Poisodonomyen-Schiefer. In Germany large numbers of most excellently preserved forms are obtained from near the small towns of Boll, Holzmaden, Ohmden, etc., at the foot of the Swabian Alps, and from the neighborhood of Banz in France. Many of the forms obtained from these localities are specifically identical with the forms from the English deposits. From the Cretaceous layers of Trichinopolis in the East Indies, and from about the same horizon of the same age in New Zealand and Australia have been collected specimens of this genus. From the Island of Gozo near Malta come fragments from layers that appear to be Miocene; if this is correct, the genus extends very much farther in time than was originally supposed, but the remains are only fragments and the age of the strata is still in doubt.

Opthalmosaurus from the Upper Jurassic of England is known only from a few fragments, but is interesting from the fact that the jaws were entirely without teeth. The paddle was broad and stout with many small phalangeal bones.

Baptanodon is from the Upper Jurassic of Wyoming. This genus was also without teeth. The paddle was very broad and the phalanges very numerous.

The great geographical range, and the large number of species indicate the extensive development of these animals in the short time that they existed on the earth. That they were fierce and predaceous is amply shown by the remains of fish scales and bones that are found in the coprolites.

SAUROPTERYGIA (*Plesiosauria*).

Aquatic reptiles, generally of large size, with long necks and heads of comparatively small size; the body very short and stout, ending in a long and powerful tail; the orbits were very small and the posterior portion of the skull shows a single tem-

poral arch. The teeth were sharp and strong, conical in form and often recurved; they were set in separate sockets or alveoli. The pectoral and the pelvic girdles in the most advanced of the group were greatly expanded to serve as a protective shield for the thoracic and the abdominal regions.

The *Plesiosaurs* descended from land-living animals with well developed limbs just as the *Icthyosaurs* did. In the earliest of the *Plesiosaurs* the fore and hind legs were those of an animal that walked on the dry land at least as well as the modern alligators, but in the later and more specialized forms, the limbs are reduced to paddles which were useless for any purpose but that of swimming. The general appearance of the brute has been aptly described as that of a "turtle strung on a snake."

There are generally recognized three families of the *Plesiosaurs:*

Nothosauridæ.
Plesiosauridæ.
Pistosauridæ.

Nothosauridæ.—These were small forms that were most nearly related to the parent form of the whole group. The limbs were more or less well adapted to progression on land and there were five functional digits on each foot.

Nothosaurus, from the Triassic (Muschelkalk) of Byreuth and from other parts of Germany and from the Tyrol and the Keupfer of St. Cassian in France, was one of the small forms. It was about nine feet long. The skull was long and flat. The orbits were small and were located in the middle portion of the skull. The temporal fossa was quite large, taking up the posterior third of the skull.

The anterior nares were small and located far forward but not at the extremity of the rostrum. The teeth were numerous, small, and of nearly equal size in the posterior portion of the jaws, they formed large recurved tusks in the fore part, and were set far apart. There were 20 cervical vertebræ, 25–30 dorsals, and about the same number of caudals.

Closely related forms from the same horizon, that are known

only from fragments, are *Chonchiosaurus*, *Simosaurus* and *Lamprosaurus*.

Lariosaurus was very much smaller than *Nothosaurus*, being less than 3 feet in length. It is known from the Trias (Muschelkalk) of Italy. The skull is triangular in outline and very much shorter than the skull of the first genus. The temporal fossæ are large, the orbits and the nares small and lying quite close together. There were 20–21 cervical vertebræ, 24–26 dorsal, and about 30 caudals. There was in this genus, as in the former, a ventral armor of small abdominal ribs.

Pachypleura, from the Trias of Italy, was very similar to *Lariosaurus*, but was even smaller. It was remarkable for the length of the tail which was nearly half as long as the body. There were about forty vertebræ in the tail. The same genus is known from the Trias of Germany.

Plesiosauridæ: large forms with the limbs developed as paddles. There were five digits on each foot, but the number of phalanges is much above the normal. The whole pectoral girdle reaches a very great development in these forms so that it forms a bony protection for the thoracic region.

Plesiosaurus.—The head of this genus was small and rather elongate, the temporal fossæ were large and the orbits and nares small. The teeth were numerous in both jaws. They were long and slender, slightly recurved and set in deep alveoli. They were somewhat large at the anterior end of the snout. The neck in some of the species of the genus, was as long as the rest of the body. There were 20–72 cervical vertebræ, 20–25 dorsals, and 30–40 caudals. There was a system of abdominal ossicles consisting of a centerpiece and two or more smaller lateral pieces. The most characteristic part of the anatomy of the animal is the pectoral girdle. The coracoids became very large and the clavicles reduced to small proportions. The extension of the coracoids of the two sides causes them to meet in the median line and they together join the clavicles and the interclavicle in front, making a thick bony cuirass covering the region. The pelvis does not show such a great expansion, but there is a

considerable development of the pubis, that parallels to some extent the extension of the coracoids.

The oldest known remains of this genus come from the Rhaetic beds of England and France (Autun). The most plentiful deposit is in the Lower Lias of Lyme-Regis in England; there are about twenty-six species known from these beds, a much larger number than is known from the continent. The continental forms are found most commonly in the Lias beds in the vicinity of Holzmaden in Germany and near Banz and Autun in France.

Eretmosaurus is quite similar to *Plesiosaurus*, being distinguished only by the greater development of the thoracic shield. A headless skeleton preserved in the British Museum is about nine feet long.

Cimoliosaurus from the Cretaceous of the United States is characterized by the complete loss from the pectoral girdle of the clavicles and the interclavicle. The scapulæ and the coracoids are extended until they meet the bone of the opposite side in the median line for a long distance and join each other in a broad suture. The whole arrangement is the most specialized of any in the group, both in the loss of the two elements and in the size of the coracoids and the scapulæ. Many similar forms that show the same thing, but with slightly different shaped bones, have been described as different genera, but were all united by Seeley in the genus *Cimoliosaurus* of Leidy. These genera are *Discosaurus*, and *Brimosaurus*, from the same horizon of the Cretaceous in Alabama and New Jersey as the original genus; *Polycotylus* from the Cretaceous of Kansas (Niobrara); *Elasmosaurus*, from the same locality and horizon as the last, is of remarkable length, one specimen from near Fort Wallace in Kansas being 45 feet long, the neck alone being 22 feet and containing 72 vertebræ; *Mauisaurus*, from the Cretaceous of New Zealand.

A summary of some of the different forms referred to this genus will give some idea of the importance it attained in the latter part of the Mesozoic time.

Cimoliosaurus, Cretaceous of New Jersey and Alabama.

C. (*Polycotylus*), Cretaceous of Kansas.

C. (*Mauisaurus*), Cretaceous of New Zealand.

C. (*Elasmosaurus*), Upper Cretaceous of Kansas.

C. (*Plesiosaurus*) *helmerseni*, Gault of England and Russia.

C. (*Plesiosaurus*) *planus*, Gault of England, Russia, and France.

C. (*Plesiosaurus*) *australis*, Cretaceous of New Zealand and Australia.

C. (*Plesiosaurus*) *chilensis*, Cretaceous (?) of Chile.

The *Plesiosaurs* were powerful, free-swimming, predaceous animals that found their chief food supply in the fishes and the smaller reptiles that inhabited the same waters. The long neck and powerful teeth must have made them more than a match for any of the aquatic forms of the time, and the fish-like form and the strong paddles enabled them to get through the water with great velocity. In no other form of this time do we find such great variety of forms and such wide geographical distribution; the only region in which their remains have not been found is South Africa. A most interesting habit of the animals was the swallowing of stones, apparently to aid in the digestive work of the stomach. One specimen from the Fort Benton Cretaceous of Kansas had about 125 of these stones in the stomach, varying in size from that of the fist to that of a pea.

Thaumatosaurus, from the Jurassic (Dogger and Kimmeridge) of England and India (Gonwanda series), and also from the Jurassic of Wurtemberg, was a peculiar form with a very large head supplied with strong teeth and a very short neck. The limbs were proportionately quite long and the bones of the proximal series were better developed than common in the *Plesiosauridæ*.

Peloneustes and *Pliosaurus* are from the Cretaceous of England. The last was of gigantic size, the skull of one being over 4 feet 9 inches in length and 2 feet 11 inches across the posterior end. The neck was rather short having only about 20 rather compressed vertebræ.

Pistosauridæ: the skull, elongate and terminating in a sharp rostrum in front; the anterior nares, very small and formed by the maxillaries and the premaxillaries; the nasals, greatly reduced and taking no part in the nares; a single foramen in the palate at the anterior end, forming the posterior nares or choanæ.

Pistosaurus is the single genus; from the Muschelkalk of France and Germany.

PYTHONOMORPHA.

The *Pythonomorpha* are specialized forms of the *Lacertilian* branch developed during Cretaceous time. They were sea-living lizards, corresponding in many particulars to the popular idea of the sea serpent. They were greatly elongated in form, the limbs were specialized as paddles, and the whole body adapted to an aquatic life. They resembled the living *Varanus* or *Monitor*. The head was long and flat; the eyes, small and located far back in the skull, were supplied with sclerotic plates. The major part of the skull was formed by the long jaws, which were furnished with sharp, conical teeth, straight or slightly curved backwards, and set in separate alveoli. The upper jaw was solid and strong, with or without a rostrum extending in front of the teeth. The lower jaw was not united at the anterior end with the jaw of the opposite side, but was attached to it by cartilage, thus allowing a great degree of freedom in the action of the two jaws. Moreover, the jaw of each side was furnished with a second joint at about the middle, which allowed the jaw to be bent out or inward in a horizontal plane, and enabled the animal to swallow the large animals upon which it preyed. The brain cavity was small, and the quadrate bone was joined to the skull loosely, as in the snakes, allowing the jaws to be opened very widely. There were a great many vertebræ, giving a great length to the neck and tail as well as to the dorsal region. The vertebræ were furnished with very perfect articular surfaces, concave in front and concave behind; besides the regular arrangement for the connection of the vertebræ there were accessory articular processes such as occur in the

snakes, allowing a very great freedom of movement to the body. The limbs were modified as swimming organs. As in the case of land forms generally which have become adapted to an aquatic life, the number of the phalanges was increased, while the shape of these and of the tarsal and the carpal bones became indefinite, and, in some cases, they were even reduced to mere flattened disks of bone.

The geographical range of the *Pythonomorpha* is rather remarkable. They are known from the Upper Cretaceous rocks only, ranging from the Upper Dakota to the Lower Laramie. They have been found in the rocks of the western part of the United States, in Kansas and the Dakotas and in the Cretaceous deposits of New Jersey and Alabama; in the Maestricht beds, Lower Danian, of Belgium; in the Upper Cretaceous of England, the Chalkbeds, which are supposed to be correlated in time with the Niobrara beds of western Kansas; in Upper Cretaceous beds of unknown position on the coast of Chile and upon some of the adjacent islands, and in the same horizon in New Zealand.

The order is divided into three groups: the subfamilies *Tylosaurinæ*, *Platecarpinæ*, and *Mosasaurinæ*. Below is an abbreviated list of the characters assigned by Williston to the various divisions.

Tylosaurinæ: hind feet functionally pentadactyl; trunk short, tail proportionately long; tarsus and carpus almost wholly unossified, phalanges numerous; premaxillaries projecting as a long rostrum in front of the teeth.

Tylosaurus.—This is one of the largest of the forms. It reached in some cases, *T. dyspelor*, a length of nearly 30 feet. There were 7 cervicals, 29–30 precaudals, 80 caudals. From the Upper Cretaceous of New Zealand, Kansas, New Mexico, and New Jersey.

Hainosaurus: less well known; from the Upper Senonian of Cipley (Brown Phosphate Chalk) in France.

Platecarpinæ: hind feet functionally pentadactyl; trunk short, tail proportionately long; carpal and tarsal bones not well ossified; premaxillaries, not projecting in front of the teeth, obtuse.

Platecarpus.—This form was of intermediate size, one genus reaching a length of about 14 feet. Cervicals, 7; precaudals, 27–28; caudals about 80, probably somewhat less than in the *Tylosaurinæ*. From Kansas, Colorado, and Mississippi.

Plioplatecarpus: from the Maestricht of Belgium.

Taniwhasaurus: from the Cretaceous of New Zealand.

Mosasaurinæ: hind feet tetradactyl; carpus and tarsus fully ossified and with not more than six phalanges in each digit; trunk rather long with a shorter tail; rostrum short.

Mosasaurus: from Belgium, England, New Jersey, Dakota, Alabama, and North Carolina. Specimens from New Jersey show a length of 32–36 feet, and some of the European forms were as long as 40 feet.

Clidastes.—This was one of the smallest of the genera. *C. pumilus* was only about 6 feet long, and no species was over 12–14. Cervicals, 7; precaudals, 42; and caudals, 70. From Kansas, Colorado, New Jersey, Mississippi, and Alabama.

Many less well-known genera have been described from the rocks of this country and Europe, showing that the group had a considerable development while it lasted.

Speaking of the group, Williston says: "The food of the Mosasaurs must have consisted chiefly of fishes of moderate size with occasional victims of their own kind. While the flexibility and loose union of the jaws undoubtedly permitted animals of considerable size to be swallowed, the structure of the thoracic girdle would not have permitted any such feats of deglutition as the *Python* and *Boa* are capable of. The animals must have been practically helpless on land. They were not sufficiently serpentine to move about without the aid of limbs, and these were not at all fitted for land locomotion. They lived in the open sea, often remote from the shores. Their pugnacity is amply indicated by the many scars and injuries they received, probably from their own kind."

PTEROSAURIA.

The *Pterosauria* or *Pterodactyls*, as they are more popularly called, were reptiles that were adapted to a flying or soaring life

in the air. Just as the preceding groups, the *Icthyosaurs* and the *Plesiosaurs* had been compelled by the great struggle between the large number of reptilian forms to seek some peculiar modes of life to maintain an existence and had taken to the water, so these forms had been compelled to seek new environment and became adapted to an aërial, or partially aërial, life. Whether they were possessed of any great power of flight or were only capable of soaring, as the flying-squirrel, is not known, but the enormous distance that their remains are found from what must have been the land at the time and the pneumaticity of their bones speak for a very well developed power of flight. There was great variation in the sizes of the animals, some being very small, while others reached a spread of 18 feet from tip to tip of the expanded wings. The bones were all hollow and provided with foramina at the extremities that seem to have filled the same function that the foramina in the bones of the birds do, that of supplying air to the interior of the bones. These two facts seem to imply that the Pterodactyls were warm-blooded, but this can not, of course be definitely settled from the skeleton. The tail was either long or short. In the cases where it was long, it ended in an expansion that served as a rudder to guide the flight of the animal. The fore limbs were very much longer than the hind limbs and were especially modified to support the organ of flight. This was a strong membrane much like that which serves the same purpose in the bats. In certain of the specimens preserved in the fine grained slates of the Solenhofen beds, the folds of the wings are preserved and even the course of the nutrient arteries may be followed. There were four digits on the front foot or wing, the last four, and the last of these, or the little finger, was enormously extended so that it was many times the length of the arm. The other fingers were short and greatly reduced in size; they ended in small claws which perhaps aided the animal to cling to the sides of the cliffs on which it lived. The wing membrane stretched from this extended finger and the arm to the weak posterior limbs. In all probability the membrane extended also between the

hind legs and for a short distance out upon the tail. The head was very bird-like, all the bones being closely united and the sutures between them disappearing early in the life of the animal. The skull was of many different forms in the different species and the jaws were almost always furnished with teeth, but in some of the more specialized of the genera these were absent.

The group is generally divided into three families:

Pterodactylidæ.
Rhamphorynchidæ.
Pteranodontidæ.

Pterodactylidæ: forms with short tails; the skull quite long and furnished with teeth; the sides of the skull anterior to the orbits broken by vacuities that possibly aided in lightening the weight of the skull. The orbits were large and there was only one temporal arch. The metacarpals were longer than one half of the length of the forearm.

Pterodactylus was about a foot long and very slender in all of its proportions. The skull was long and bird-like and furnished with teeth at the anterior ends of the jaws only. There are many species of this genus known, the most of which come from the Upper Jurassic layers (Lithographic slates) of Germany, near Eichstat and Bayern. A few specimens have been taken from the Upper Jurassic of France in the department of Ain and the Kimmeridge clays of England have furnished isolated bones of the same genus.

Rhamphorynchidæ: forms with long tails which are frequently accompanied by ossified tendons; the skull only moderately elongate; the jaws furnished with teeth throughout their whole length which grew smaller towards the posterior part of the jaw, those in front being long and slender. Metacarpals shorter than the half of the forearm. The fifth toe of the hind foot taking some part in the support of the wing membrane and showing a much greater development than the other toes.

Dimorphodon, from the Lias of Lyme-Regis in Dorsetshire, England, was a much stouter form than the *Pterodactylus;* the

head was short and high with strong teeth and small lateral vacuities. The whole animal had a length of nearly three feet.

Rhamphorynchus had a rather long snout, edentulous at the anterior end in both the upper and the lower jaws. The remaining portions of the jaws were filled up with rather long and slender teeth which were directed forward. The teeth were of different sizes in the jaws, but, in general, the largest were in the anterior part. The neck was short and strong and the cervical vertebræ very short. The sternum was broad and furnished with a median keel for the attachment of strong muscles as in the modern flying birds. The tail was long with 30–36 vertebræ and strengthened by tendons. The wing of this form was more slender than in the majority of the *Pterodactyls* and resembled that of the night hawk or goatsucker. The genus is known from the Upper Jurassic (Lithographic Slates) of Bayern and Wurtemberg.

Scaphognathus was much like the preceding, except that the teeth extended to the extremities of the jaws and were few in number. They were directed vertically instead of forward. Specimens of this genus are known from the Upper Jurassic of Germany and of England.

Ornithochierus is the name given to a very large form that is known from numerous fragments in the Jurassic deposits of England. The jaws seem to have been furnished rather sparsely with teeth of considerable size which extended to the extremity of the jaws. There are a great many species represented in the rocks of England from the Wealden to the Cretaceous, in all about 25. One form from the Chalk, *O. giganteus*, must have possessed a spread of wing of about 15–18 feet.

Pteranodontidæ: the skull long and terminating in sharp, edentulous jaws; no lateral vacuities in the skull; the tail, short.

Ornithostoma was originally described from the fragment of a jaw from the Chalk of England, but no more of it was known than that it was without teeth.

Pteranodon (?), from the Upper Niobrara, Cretaceous of Kansas, was a very large form with toothless jaws; probably

synonymous with *Ornithostoma*. Head much elongate; the jaws slender, pointed and wholly wanting teeth; external nares and antorbital vacuities united; supratemporal fossa of large size; occipital crest elongated; the anterior dorsal vertebræ united and bearing a supraneural plate for articulation with the scapulæ; tail short and small; four functional toes on the hind foot.

Speaking of the general appearance of the animal, Dr. Williston says: "Altogether the skeleton of *Ornithostoma* presents some remarkable characters. I believe there is no other reptile in which the prosthenic features are carried to as high a degree as in this. The disproportion between the fore and hind extremities is almost ludicrous. The pelvis is exceedingly small, the legs not only small but weak in all respects. That the animal could have stood on its feet free on the ground I do not believe possible. The neck vertebræ are relatively stout, but the neck was not remarkably elongated, to carry such a head as the animal possessed. Furthermore, the remarkable mode of articulation of the neck and the anterior dorsal vertebræ seem to indicate a restricted range of torsion, though tolerably wide sagittal flexion. The occurrence of the remains of the large species in strata evidently formed remote from the shore lines, as shown by the absence of other animals, turtles, etc., indicates great powers of flight. Furthermore, it is rare that a single bone of a *Pterodactyl* is found unassociated with others, and almost invariably the wing bones are found more or less in connection, indicating either tough and horny tendons or a rapid sinking in the water, which might happen from the filling of the hollow bones with water through their pneumatic openings.

"Notwithstanding the enormous expanse of the wings, I do not think these animals could have weighed much when alive. I doubt very much if one of the largest species reached twenty pounds."

Nyctodactylus was a form from the Cretaceous of Kansas (Niobrara) that differed from the previous genus principally in the size, the wings measuring less than ten feet when expanded. The jaws were almost certainly edentulous.

TESTUDINATA.

The turtles may be briefly described as reptiles that have lost the teeth completely, and have developed an external skeleton in the shape of a bony case that is more or less complete and protects the body of the animal. There is little doubt that they are derived from animals that did not possess such a structure, but the point of their divergence from the primitive stem is so ancient that it has not yet been detected, and the oldest form that we know is a member of the most specialized group of the turtles.

The order is generally divided into three suborders:

Trionychia.
Pleurodira.
Cryptodira.

The *Tryonichia* differ from the typical forms of the *Testudinata* in that the bony exoskeleton is largely represented by a thick, leathery skin, which has given them the name of Soft-shell Turtles. Beneath this skin is developed a series of small bony plates with a characteristic sculpture, that in many places form the chief remains of the forms.

Trionyx is the most common of the extinct forms. The oldest remains are from the Upper Cretaceous of New Jersey; these are, for the most part, fragmentary remains of the plates of the carapace. From the Upper Cretaceous, Laramie, of the western part of the United States and British America, have been collected a large number of specimens. Through all the deposits of Tertiary age in Europe, specimens of this genus have been found; in the United States it is found throughout the Tertiary of the eastern part, but in the west seems to be confined to the lower layer, the Eocene. Remains of still living species have been found in the Pleistocene beds of India and Burmah.

The *Cryptodira* are by far the most important group of the Testudinata, both in number of species and their distribution in time. The group is characterized by the fact that the pelvic bones are not anchylosed to the carapace and the plastron above and below. There were developed so many forms that it is

impossible to consider more than a few of the genera. There seems to be a division of the group in very early times into land-living and water-living forms. The first of these gave rise to the common swamp and land turtles of today, and the second group to the sea turtles, the *Pinnata*.

The second of these groups may be considered first; *Dermochelys* is the most specialized of the genera. This is a gigantic form still living in all of the oceans, though little known from its almost exclusively pelagic habits. The carapace has entirely disappeared and is replaced by a tough leathery skin that has won for them the name of "Trunk-backs or leather-turtles." The plastron is less completely removed but there is a large space in the center, between the bones called the fontanelle. The fore limbs are developed as flippers, the anterior pair being much the longest.

The more common members of the same division are the Loggerhead and Green turtles. In these the carapace and plastron are less reduced, but both show large vacuities that indicate the steps by which the condition in *Dermochelys* was produced.

Protostega is the earliest of the definitely known forms. It is from the Upper Cretaceous (Niobrara) of Kansas. Similar in many respects to the recent *Dermochelys*, it still shows many primitive characters that indicate its separate position. The carapace was not ossified, but the proximal ends of the ribs show lateral expansions that would, if carried a little farther, produce the condition found in the *Chelonia* (the most primitive of the living sea turtles). The genus was one of the largest of the order. One specimen measured nearly or quite seven feet in length.

Protosphargis, from the Upper Cretaceous of Italy, *Eosphargis*, from the London Clay (Eocene), and *Psephophorous*, from the Miocene of Germany, are all closely related to *Protostega* and show successive steps toward the condition of *Dermochelys*. The great geographical extent of these forms seems to indicate that they possessed the same roving and pelagic habits that characterize their nearest living relative.

Remains of the closely related forms that culminated in the Cheloniidæ (*Chelonia*, etc.) and differed from the previous forms only in the more complete carapace, are found in the Cretaceous of Europe and America. These forms show characters of the land turtles as well as of the sea turtles, and are in all probability the forms that represent the branching of the primitive stem of the turtles. Such forms are *Propleura*, from the Cretaceous of New Jersey, *Osteopogys*, from the same locality, *Toxochelys*, from the Niobrara, Cretaceous, of Kansas, and *Euclastes* from the Cretaceous of New Jersey, the Greensand of Cambridge, England, the Eocene of England and France. Forms more common on the continent are *Eurysternum*, from the Upper Jurassic of Germany, *Idiochelys*, from the same horizon in France (Cerin) and Germany (Kelheim). *Hydropeltæ* is quite frequently found associated with the remains of *Idiochelys*.

Of the common swamp and land turtles more is known than of the sea turtles. The ancestors of the *Chelydridæ*, or common snapping turtles, are found as far back as the Upper Jurassic. *Platychelys* from this horizon, at Kelheim, is one of the typical forms. In *Platychelys* there was an extra pair of plates in the plastron, the mesoplastra, that did not reach the middle line from the sides.

Helochelys, from the Greensand (Cenomanian) of Kelheim, was quite similar to the preceding. The whole surface of the carapace was covered with wart-like projections, except the lines that marked the union of the horny plates with the bony ones beneath. In this form the mesoplastron was narrow but complete, and extended from each side, meeting in the middle line. It was quite large, about a foot and a half long.

Compsemys is a very large form, distinguished by the fact that the plates of the carapace are joined by suture to the peripherals, and are marked by small pit-like excavations. It is very plentiful in the Upper Cretaceous layers (Fort Union and Laramie) of the western part of this country.

Anostira was a small form from the Lowest Eocene (Bridger) in Wyoming.

Apholidomys and *Pseudotrionyx* are from the Eocene of France. The true land turtles, *Testudo*, mostly, are characterized by the great elevation of the carapace and the smoothness of its bones. The claws of the toes are in many cases shortened till they appear as broad nails. The earliest forms known are from the Eocene of Wyoming and New Mexico, the Wasatch and Bridger. In Europe the earliest forms occur in the Oligocene. Throughout the Miocene and the Pliocene layers of both the old and the new world, the genus abounds. The best region for the remains, however, is the Bad Lands of South Dakota, Miocene or Oligocene, where they occur in great abundance.

Especially remarkable was the gigantic *Collosochelys* of the Siwalik Hills of India (fresh-water Miocene). The animal was fully 18–20 feet long, the carapace alone being 12 feet long and 8 feet high.

From the Pleistocene of Queensland, Australia, comes the peculiar form *Meiolania*, which possessed horns or bony protuberances on the skull.

During Pleistocene times many of the islands of the East Indies were inhabited by enormous land turtles. Remains of such are known from Mauritius and Rodrigues. Similar remains are known from the Island of Malta and on the Galapagos Islands off the coast of Central America there are still living forms of the same group.

The *Pleurodira* are the forms in which the bones of the pelvis are joined by sutural union to the bones of the carapace and plastron above and below. They are few in number in recent times, and were little if any more numerous in past time, though, peculiarly enough, the most ancient turtle known is a member of this suborder. *Proganochelys*, from the Upper Triassic (Keupfersandstein) of Germany, *Plesiochelys*, from the Upper Jurassic of England, and *Bothremys*, of the New Jersey Cretaceous, are also members of the same group.

PROGANOSAURIA.

These forms are of the greatest interest from a phylogenetic standpoint. They are generally regarded as the most primitive

form of the reptiles, and from them are probably derived the majority of the reptilian orders. They are characterized by a very generalized structure of the skull and skeleton that in many regards closely approximates the condition of the *Amphibia*. The bones were not completely ossified; there were many abdominal ossicles, and the vertebræ were perforated for the passage of the notochord. The group is extinct.

Paleohatteria, the earliest of the order, is found in the Rothliegende, Upper Permian, deposits of Niederhasslich near Dresden. It was a small lizard-like animal about a foot long; the teeth were small and conical, and were developed on the vomer and palatine bones of the mouth as well as in the jaws, a character common in the *Amphibia*.

Proterosaurus is another form much longer and more slender, about six feet in length. It is peculiar in the fact that the vertebræ of the neck are only seven in number, and are greatly elongated, as is common in the long-necked mammals. It is from the Keupferschiefer of Thuringia.

Mesosaurus, from the Permian or Permo-Triassic of South Africa, is represented by the impression of the anterior half of an animal that was much like the Plesiosaurs in general appearance; the neck was long and slender, and the head had the same kind of teeth. The posterior portion of an animal that is regared as belonging to the same genus has been found in the Permian of Brazil.

RHYNCHOCEPHALIA.

The members of this order differ only in degree from the preceding. The bones are better ossified; the abdominal ossicles are reduced in number and simplified in arrangement; the notochordal opening in the vertebræ is smaller and the skull has advanced toward the modern type of the reptiles. The group is of great importance, both because of the variety of the forms produced and because it is in all probability the direct ancestor of the later reptiles. The living *Lacertilia* and *Ophidia*, and, in all probability, the *Testudinata*, as well as the extinct *Plesiosaurs*, *Icthyosaurs*, *Pythonomorpha*, *Pterosauria*, *Dinosaurs*, *Croco-*

dilia, and possibly the *Theriodonta* must be regarded as the descendants of this order. Through the *Dinosaurs* the Birds are related to the order, and through the *Theriodonta* the Mammals.

Rhynchosaurus and *Hyperodapedon* are two forms from the Triassic, Elgin Sandstones of Scotland and the Triassic beds of Warwickshire in England. The latter genus has also been described from the Maleri, Triassic, beds of the East Indies. They were small forms, quite similar in external appearance to the modern lizard, except that the incisor teeth of the jaws were developed as great curved processes. The roof of the mouth was covered with teeth, and there was a single external nostril.

Homæosaurus and *Sapheosaurus* are from the Upper Jurassic of Germany and France, notably the Lithographic Slates of Kelheim. They were very similar to the modern lizards in appearance.

Sauranodon, from the Jurassic of Cerin in France, was similar to the foregoing, except that the jaws were greatly extended and were edentulous.

Champsosaurus, from the Upper Cretaceous, Laramie of Wyoming, and the lowest Eocene, Puerco of New Mexico, and *Simædosaurus*, from the Eocene of France and Belgium, are very peculiar in that the articular faces of the vertebræ are nearly flat, instead of being deeply concave, or even perforated, as in the majority of the *Rhynchocephalia*. It has been suggested that the two forms are identical, but as the skull of *Champsosaurus* is not known it is impossible to settle the question. The skull of *Simædosaurus* was long and slender, with an anterior rostrum much like that of the modern Gavial of the Indian rivers.

Sphenodon, from New Zealand, is the single living member of the order. It probably appeared in the Jurassic, though it is still unknown in the fossil state.

The modern *Lacertilia* and *Ophidia* are the direct descendants of the *Rhynchocephalia*. The chief differences are the loss of the lower one of the temporal arches (in some cases of both) and the loss of the abdominal ossicles. Moreover, the deeply biconcave character of the vertebræ, amounting in most cases to a

perforation of the centrum, is absent in most of the *Lacertilia* and all of the *Ophidia*. The loss of the limbs in the snake is but a secondary character, and is nearly accomplished in many genera of the lizards.

The earliest of the *Lacertilia* is from the Isle of Purbeck in Dorsetshire, England. All that is known of the specimen are the imperfectly preserved remains of the skull and some of the scales. The genus is called *Macellodon*.

Hydrosaurus, from the Lower Cretaceous of the Island of Lesina in the Mediterranean, was very similar in appearance to the modern monitors. (This genus was the direct ancestor of the great, specialized group of the *Pythonomorpha* developed during the Cretaceous.)

Dolichosaurus and *Coniosaurus*, from the Upper Cretaceous of England, and *Tylosteus*, from the Cretaceous of North America, are typical lacertilians. The Tertiary rocks of both hemispheres abound in the remains of the *Lacertilia*. The development of these forms began so early that even in the earliest Eocene we find representatives of the families and even of the genera of today. Zittel in his *Handbuch* enumerates from the Eocene of Wyoming the remains of *Chameleo*, *Iguanavus*, *Glyptosaurus*, *Saniva*, *Xestops*, *Thinosaurus*, and *Tinosaurus;* from the Eocene Phosphorite (Upper Eocene) of Quercy, *Agama*, several genera of the *Iguanidæ*, *Paleovaranus*, and *Lacerta*.

In the Miocene deposits of Europe are found many of the existing genera. In the Miocene of the western states, especially Colorado, are found such genera as *Exostinos*, *Aciprion*, *Diacium*, *Platyrachis*, and *Crematosaurus*.

Most of the remains of the Pliocene and the Pleistocene formations belong to existing genera and species, with the exception of the Australian *Megalania* and *Notiosaurus*.

The *Ophidia* are very poorly known from the fossil forms. The only parts preserved are the vertebræ. With the single exception of *Symoliophis*, from the Cretaceous of Charente, the known fossils are from the Tertiary layers. From the London Clay (Eocene) and the Eocene sand of France come the remains of

large Python-like forms. The Eocene of New Jersey has yielded one form, *Titanophis*, and the Puerco of New Mexico *Helegras*. The Eocene of Wyoming has yielded *Boavus*, *Lithophis*, and *Limnophis*.

The Miocene layers of both this country and Europe have afforded many scattered fragments that belong mostly to living families. The Pliocene and the Pleistocene contain only genera and species of living forms.

CROCODILIA.

The *Crocodilia* are lizard-like forms of generally, large size possessing many characters that indicate their origin from the *Dinosaurs* and the *Rhynchocephalia*. The tail is long and powerful, the jaws armed with strong, simple teeth, the skull flattened, and the anterior end produced into a rostrum of varying length; there is generally developed in the skin a series of bony plates that in some forms is confined to the back, and in others extends to the skin of the abdomen as well; there are generally developed abdominal ribs in the body wall.

The order is divided by Zittel into three suborders:

Parasuchia.
Pseudosuchia.
Eusuchia.

The *Parasuchia* are the nearest of all the order to the ancestral stem of the *Crocodilia*. The possession of paired anterior nares, located far back on the upper surface of the skull, of large preorbital openings in the skull; the structure of the base of the skull and the palatal region, and the structure of the shoulder girdle are all characters that unite the suborder with *Dinosaurs* and the *Rhynchocephalia*.

Belodon, the most common form, was about nine feet long; the skull extended forward in a long, high, and laterally compressed rostrum; the jaws were filled with strong, simple teeth; there were two rows of plates extending down the middle of the back, and others less regularly developed in the skin of the sides; the limbs were weak and probably had about the same

proportions as in the modern Crocodile. Remains of the genus are known from the Trias of Germany, and from the same horizon in both the eastern and western parts of the United States.

Stagonolepis and *Parasuchus* are forms separated from the foregoing by minor characters of the skull and teeth. The first is known from the Triassic (?) Elgin Sandstones of Scotland, and the latter from the same horizon, Maleri Sandstone of the East Indies.

Pseudosuchia.—These are very peculiar forms from the Triassic rocks; the genera were all small, not over a foot long at the outside; the most characteristic thing about them was the development of a cuirass of bony plates in the skin, that protected every part of the body from the head to the tail, and included the ventral as well as the dorsal side of the body.

Ætosaurus, from the vicinity of Stuttgart in Germany, is the best known form. A single slab in the Stuttgart Museum has the remains of twenty-four individuals preserved in it.

Typothorax is the name given to a form described by Cope from fragments of the ribs and the dermal plates discovered in the Triassic rocks of New Mexico.

Eusuchia.—This suborder is in general characterized by the shortness of the premaxillaries and the location of the external nares far forward on the snout; the roofing over of the palatal portion of the mouth by the gradual extension inward of the palatine and maxillary bones, and the crowding of the internal nares back toward the posterior part of the mouth. There are two sections described, the *Longirostres* and the *Brevirostres;* the first possesses a long, slender rostrum formed by the extension of the maxillary bones; the anterior nares are not divided at the anterior extremity, and the teeth are little differentiated. The *Brevirostres* have a short snout, with the anterior nares divided, and the teeth more or less differentiated.

The *Longirostres* contain several families, typical of which are the *Teleosauridæ* and the *Gavialidæ*. The *Teleosauridæ* are the oldest known of the *Eusuchia*, specimens being known from the Lias. The oldest of the forms were marine, and the latter

inhabited fresh water. They were powerful swimmers, with much better developed limbs than the modern Crocodiles. The skin of both the back and abdomen was strengthened by the presence of bony plates that formed a very perfect armor. Prominent forms were *Pelagosaurus* from the Upper Lias of Germany and France; *Mystriosaurus*, from the same horizon in Germany; *Steneosaurus*, from the Upper Jurassic of England and the continent; *Teleosaurus*, from the same horizon and localities, etc. Many genera are known from layers younger than the Jurassic, and these seem to lead naturally to the *Gavialidæ*, which are known from the late Tertiary of India, and are found living in the rivers of that country.

The *Brevirostres* became prominent in the Upper Jurassic, and occupied a very important part in the later times. Of five families described two are still living.

Alligatorellus was a small form from the Upper Jurassic of France; it was less than a foot long, and was characterized by the possession of biconcave vertebræ.

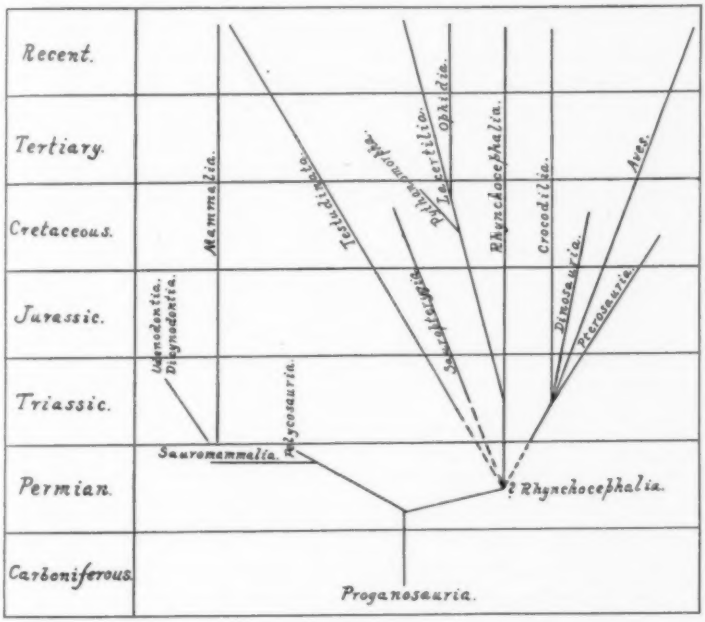
Goniopholis, from the Upper Jurassic of England and the continent, was a much larger form than the preceding. It possessed biconcave vertebræ; there was a double line of dermal plates in the skin of the back, and the ventral surface of the body was protected by a large number of plates joined by suture. Similar forms have been described by Cope and Marsh, from the Jura of the Rocky Mountains, under the names *Amphicotylus* and *Diplosaurus*. These may be synonymous with *Goniopholis*.

Bernissartia is from the celebrated fossil region near Bernissart in Belgium. It is characterized by the fact that the teeth are differentiated into separate sizes in the jaws. *Theriosuchus*, from the Purbeck of England, is regarded as belonging to the same family.

The true Alligators and Crocodiles appeared in the fresh water deposits of the Cretaceous and extended to the present time. *Diplocynodon* is one of the earliest of the true Alligators. Remains are found in the deposits of both Europe and North America.

The genus *Crocodilus* appeared in the Cretaceous of France. Remains are known from the Tertiary deposits of both the old and the new worlds as late as Pliocene time, when they seem to have disappeared from all regions except those in which they are still found, tropical Africa, South America, and the East Indies.

The connection between the various groups of reptiles may be seen from the following table, which is slightly modified from one published by Baur.



E. C. CASE.

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EDITORIAL.

ASTRONOMERS are not alone in appreciating the interest which attaches to the newly discovered planet DQ. Its peculiarities promise to be suggestive at least in respect to questions of planetary origin in which geologists are concerned almost equally with astronomers. The new planet breaks across that rather forcefully deduced law of symmetry which has been thought to prevail throughout the solar system and which has been somewhat too influential perhaps in controlling hypotheses of its origin. The little stranger pays no respect to Bode's law, and is eccentric in other particulars. Its mean position lies between the earth and Mars, and its period of revolution is 645 days, while that of Mars is 687. Its orbit, however, is so eccentric that in aphelion the planet's path lies far outside of the Martian orbit in the zone of the asteroids, while in perihelion it passes within fourteen million miles of the earth, according to the provisional computations made from the earlier observations. One of the most interesting features of the new planet lies in the fact that its velocity at perihelion is greater than that of the earth, although it is farther from the sun. Should the two orbits be brought into coincidence by a suitable perturbation and a collision ensue, the velocity of the outer body would be the greater, at the moment of collision, though on the average it would necessarily be less. The effect of such a collision on the rotation of the earth would depend upon the particular point at which the stroke of the smaller planet was dealt. The probabilities, however, are in favor of a stroke which would accelerate the present *direct* rotation of the earth, or which would, if the earth had no rotation, impart to it a rotation in the same direction as that which it now possesses. It has been urged that meteoroidal bodies revolving in a ring around the sun would, on

union by collision, give rise to *retrograde* rotations, because the orbital velocities of the inner bodies are the greater, and this has been regarded as a serious objection to the aggregation of the earth and all but the outermost planets from a ring of discrete matter of the type of the Saturnian rings as distinguished from an aggregation from a gaseous ring after the manner of the Laplacean hypothesis. (Faye, *Sur l'Origine du Monde*, 1896, pp. 165, 270–281). The writer has, however, pointed out that, if the aggregation of such discrete matter took place through the development of eccentric orbits which cut each other's paths and thus led to collision, the bodies pursuing the outer orbits would be moving faster *at the points of collision* than those pursuing the inner orbits, and that on the average the rotations resulting from the collisions would be direct (A group of Hypotheses Bearing on Climatic Changes, JOURNAL OF GEOLOGY, Vol. V, No. 7, 1897, p. 668). The new planet furnishes us with a concrete illustration of the principle urged. It has been estimated that, at the time of its greatest approximation, the new planet will be moving 500 feet per second faster than the earth, a figure which is doubtless subject to considerable correction from fuller data. The discovery of this rather erratic body has renewed the previous suggestion that small planetoids may not be rare in other tracts than the asteroidal belt between Mars and Jupiter. It will doubtless have some influence in reopening for renewed consideration the mode of aggregation and the past history of the solar system, a consideration which has been rendered opportune by the serious, if not fatal, objections to the accepted gaseous hypothesis which have arisen from the application of the kinetic theory of gases.

T. C. C.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

Van Hise,[2] Bayley, and Smyth map and describe[3] the geology of the Marquette iron-bearing district of Michigan. The pre-Cambrian rocks of the district comprise three series, separated by unconformities. These are the Basement Complex or Archean, the Lower Marquette, and the Upper Marquette, the two latter constituting the Algonkian for this district. All of these are cut by basic intrusives. The pre-Cambrian rocks are unconformably overlain by Cambrian sandstone.

The Basement Complex occurs in two main areas, one north of the Marquette series, called the Northern Complex, and one south of the Marquette series, called the Southern Complex. There are also isolated areas within the Algonkian. The oldest rocks of the Basement Complex are thoroughly crystalline, foliated schists and gneisses. A close field and laboratory study has failed to detect in them any evidence of sedimentary origin. These gneisses and schists have been cut by various igneous rocks at different epochs. The latter occur both in the form of great bosses and in dikes, sometimes cutting, sometimes parallel to, the foliation of the rocks. In the area of the Northern Complex there have been volcanic outbursts, and a vast series of lavas, agglomerates, greenstone-conglomerates, and tuffs have been piled up. By far the greater part of the volcanic material is of an intermediate or basic character.

The Northern Complex is treated under the divisions of Mona schists, Kitchi schists, gneissoid granites, hornblende-syenites, basic dikes, acid dikes, peridotite, and ferruginous veins. The Mona and Kitchi schists are greenstone-schists, which are believed to be largely

[1] Continued from page 541, Vol. VI., this JOURNAL.

[2] The Marquette iron-bearing district of Michigan, by C. R. VAN HISE and W. S. BAYLEY; with a chapter on the Republic Trough by H. L. SMYTH: Mon. U. S. Geol. Surv. No. 28, 1896, pp. 1 – 607. With atlas of 39 plates. Preliminary report on same district, published in the 15th Ann. Report U. S. G. S., 1895, pp. 477–650.

[3] The Algonkian rocks are described by VAN HISE; the Basement Complex and later igneous rocks are described by BAYLEY; the Republic Trough is described by SMYTH.

recrystallized volcanic materials. Their original forms included both tuffs and lavas. The gneissoid granites and syenites are plutonic intrusive rocks within the greenstone-schists. The basic dikes are mainly diabase. The peridotite is older than the Cambrian sandstone and younger than the greenstone-schists of the Basement Complex. The ferruginous veins are believed to be water-deposited, and were formed previous to the deposition of the Lower Marquette series.

The Southern Complex differs from the Northern Complex in the smaller quantity of greenstone-schists in the former and in the presence in it of the micaceous and hornblendic schists, and the Palmer gneiss. It is treated under the divisions micaceous schists, amphibole-schists, gneissoid granites, Palmer gneiss, and intrusives. The micaceous schists include muscovite-schists, biotite-schists, feldspathic biotite-schists, and hornblendic biotite-schists. They are thought to be mashed acid eruptives. The amphibole-schists include greenstone-schists, hornblende-schists, and micaceous hornblende-schists. They are shown to be mashed basic eruptives. The granites and dike materials are similar in their essential features to the corresponding rocks of the Northern Complex. The granites are younger than the schists, since dikes from them intrude the schists. The Palmer gneisses occur only on the borders of the granite areas, between these and the Marquette sedimentaries, and are apparently in most cases extremely mashed phases of the granites.

The isolated areas of the Fundamental Complex within the Algonkian are chiefly gneissoid granites and schistose greenstones, that differ in no essential respect from the corresponding rocks of the Northern Complex and Southern Complex.

The Lower Marquette series is composed of the following formations, given from the base upward: The Mesnard quartzite, the Kona dolomite, the Wewe slate, the Ajibik quartzite, the Siamo slate, and the Negaunee iron formation. There is no break between these formations; the series is a continuous one.

The Mesnard quartzite is chiefly a metamorphosed sandstone. However, at the bottom of this formation is a conglomerate, which in grading into the sandstone passes through slate and graywacke. The conglomerate is basal, being composed of detritus from the Basement Complex. At the top of the formation is a slate. The Mesnard quartzite is the first deposit of the westward transgressing Lower Marquette sea. By the time the sea had advanced westward a short

distance upon the Marquette district, the Kona dolomite began to be formed, and hence the Mesnard formation is confined to the eastern part of the district. The thickness of the Mesnard quartzite is from 150 to 670 feet.

The Kona dolomite is largely an altered limestone, but it includes interstratified layers of slate, graywacke, and quartzite, with gradation phases between these and the pure dolomite. The Kona dolomite, like the Mesnard quartzite, is confined to the eastern part of the district. The dolomite varies through a slate into the Mesnard quartzite below, and by a lessening of the calcareous constituent gradually passes into the Wewe slate above. The thickness is from 425 to 1375 feet.

The Wewe slate is chiefly a metamorphosed mudstone, but with the slates are conglomerates, quartzites, graywackes, mica-slates, and mica-schists. The Wewe slate, like the two previous formations, is confined to the eastern part of the district. The formation grades into the Kona dolomite below and the Ajibik quartzite above. The thickness is from 550 to 1050 feet.

The Ajibik quartzite, is mainly a metamorphosed sandstone, which in different parts of the district, depending upon various conditions, has been transformed into quartzite, cherty quartzite, ferruginous quartzite, ferruginous cherty quartzite, quartz-rock, and quartzite-breccia. The time of the Ajibik quartzite marks a rapid advance to the west of the Lower Marquette sea, and therefore the formation extends to the western end of the district. In the eastern part of the area the Ajibik quartzite grades down into the Wewe slate, but for the major part of the district it rests unconformably upon the Basement Complex. At many localities contacts and basal conglomerates are known. The Ajibik quartzite grades above either into the Siamo slate or into the Negaunee iron formation. The thickness is from 700 to 900 feet.

The Siamo slate is chiefly an altered mudstone, although locally it is a graywacke or quartzite. The larger area of exposure of the formation is confined to the eastern part of the district, although a belt of the formation runs near the north side of the Marquette series to the west end of the district. The Siamo slate grades into the Ajibik quartzite below and into the Negaunee iron formation above. The thickness is from 600 to 1200 feet.

The Negaunee iron formation is nonfragmental, heavily ferruginous

throughout, and contains the greater iron ore deposits of the district. The formation comprises sideritic slate, which may be grüneritic, magnetitic, hematitic, or limonitic; grünerite-magnetite-schist; ferruginous slate; ferruginous chert; jaspilite, and iron ore. Large quantities of intrusive greenstones are associated with the formation, the masses of which vary in magnitude from great bosses two miles or more long and a half mile wide to small dikes. The largest area of the Negaunee formation is in the east-central part of the district. From this area two belts extend west to the western end of the district. Upon the whole the formation is soft, and occupies lowlands between the more resistant greenstones and the Ajibik quartzites. The formation is underlain by the Siamo slate or Ajibik quartzite, into which it grades, and is overlain unconformably by the Upper Marquette series.

The sideritic slate is the original form from which the other varieties of rock have developed. The grünerite-magnetite-schists were formed by partial recrystallization of the silica, by oxidation of the iron oxide in part to magnetite, by a union of a part of the silica and iron protoxide, producing grünerite, and with the loss of carbon dioxide. The ferruginous slates are the direct result of the decomposition of the iron carbonate and the peroxidation of the iron, with partial or complete recrystallization of the silica. The ferruginous cherts differ from the ferruginous slates in that the iron oxide and the chert are largely concentrated into alternate bands. The jaspilites differ from the ferruginous cherts in that each of the quartz grains of the chert bands is stained red by included hematite. The iron ores resulted from the concentration of the iron oxides through the agency of downward-percolating waters. These concentration-bodies usually occur upon impervious basements in pitching troughs. The pitching troughs are formed by the Siamo slate, the Ajibik quartzite, a mass or dike of greenstone, or by some combination of these. The ore deposits are likely to be of large size where, as a result of the folding, the iron-bearing formation is much fractured, thus permitting the ready access of percolating waters. The ore deposits occur at the bottom of the Negaunee formation, within the Negaunee formation, and at the contact horizon between the Negaunee formation and the overlying Ishpeming formation. From the position of the ore deposits above the impervious formations, it is concluded that their concentration occurred during or subsequent to the folding which took place later than Upper Marquette time.

The Upper Marquette series is composed of the following formations, from the base upward: The Ishpeming formation, the Michigamme formation, and the Clarksburg formation, in conformable succession.

The Ishpeming formation includes two classes of rocks, which are called the Goodrich quartzite and the Bijiki schist. These rocks are sufficiently different to have different formation names, but the Bijiki schist for the west end of the district occupies a part of the horizon of the Goodrich quartzite in the central part.

The Goodrich quartzite includes quartzites, micaceous quartz-schists, mica-schists, mica-gneisses, and at the base a basal conglomerate. For the major part of the district this conglomerate rests upon the Negaunee formation, and the rock is an ore, chert, jasper, and quartz conglomerate. At a few places the Archean rocks are subjacent, and here their materials predominate in the conglomerate. The Goodrich quartzite is confined to the central and western parts of the district. For the major part of the district it rests unconformably upon the Negaunee formation. In places erosion has cut through the Negaunee formation into the Ajibik quartzite, and in a few cases even to the Archean, and here the Goodrich quartzite may be found resting on the lower formations. For the greater part of the area the Goodrich quartzite grades up into the Michigamme or Clarksburg formation, but in the northwestern part of the district it passes up into the Bijiki schist. The thickness is from 600 to 1550 feet.

The Bijiki schist is a banded grünerite-magnetite-schist, which has been derived by metasomatic and dynamic processes from an impure siderite. It is confined to the western part of the district. The Bijiki schist grades into the Goodrich quartzite below and into the Michigamme formation above. The thickness is from zero to 520 feet.

The Michigamme formation includes slates, graywackes, mica-schists, and mica-gneisses. The formation is exposed in a single large belt, running from the center to the western end of the district. It grades below into the Goodrich quartzite, Bijiki-schist, or Clarksburg formation. The thickness cannot be accurately estimated, but it is probably as much as 2000 feet.

The Clarksburg formation is composed predominantly of volcanic materials, embracing basic lava flows, tuffs, ashes, and breccias, which locally are interleaved with or grade into slate, graywacke, or conglom-

erate. Much of the material has been profoundly metamorphosed, and schist-conglomerates, mica-schists, and hornblende-schists have resulted. All of these rocks are cut by dikes and masses of greenstone. The formation is confined to the south central part of the district. The volcanic material was poured out from the number of vents, the more important ones which have been recognized being located near Clarksburg, Greenwood, and Champion. The formation grades into the Ishpeming formation or the Michigamme formation below, and into the Michigamme formation above. The Clarksburg formation belongs in age, either between the Goodrich quartzite and the Michigamme formation, or near the base of the latter. No estimate of the thickness can be given.

The igneous rocks, other than those of the Clarksburg formation, are divided for convenience in discussion into two classes, in the first of which are placed those associated exclusively with the beds below the Clarksburg formation, and, in the other, those cutting also the beds above the Clarksburg. The rocks are all basic. The older rocks occur as dikes, bosses, sheets, and tuff beds, although the latter two are subordinate. The post-Clarksburg greenstones comprise only dikes and bosses. It is conjectured that these later greenstones may be the equivalents of some of the Keweenawan eruptives.

Evidence of the unconformity between the Lower Marquette series and the Basement Complex is clear and abundant. At numerous places in the district the actual contacts of the basal conglomerate of the Marquette series and the Fundamental Complex may be seen. In all of these cases the detritus is most distinctly waterworn, and, while the major part of the material in each case has been derived from the immediately subjacent part of the Basement Complex, other material not occurring in the immediate neighborhood is found, thus showing conclusively that these rocks are not reibungs or fault breccias. There may be mentioned the principal localities at which contacts are well exposed.

At the east end of the south side of the Marquette district there are several localities, from Lake Superior to west of Lake Mary, where a conglomerate is found bearing numerous bowlders of granite, gneiss and schist, identical with the rocks constituting the Basement Complex immediately adjacent. In Secs. 22 and 23, T 47 N, R 26 W, are two islands of the Basement Complex, about which are found magnificent exposures of great bowlder-conglomerate and recomposed granite,

resting with visible contact upon the Basement Complex, and composed of material mainly derived from it. South of the Cascade range, there are again a number of localities from Secs. 34 to 32, T 47 N, R 26 W, where there are basal conglomerates, the great bowlders again being mainly identical with the adjacent granites, gneisses, and schists of the Basement Complex. South of Summit Mountain, in the west half of Sec. 25, T 47 N, R 27 W, is an exposure of the basal conglomerate. The conglomerate grades downward into a schist which is scarcely distinguishable from the Palmer gneiss, with which it is in contact. The next contact to the west is in Sec. 28, T 47 N, R 27 W, where the phenomena are similar to those south of Summit Mountain. At the end of the Republic Trough a conglomerate hangs with visible contact upon the flank of the Archean granite, bearing well rounded waterworn bowlders from it.

At the north side of the Lower Marquette series, and near the east end of the district there is exposed a magnificent basal conglomerate about three miles west of Marquette, north of Mud Lake. The next contacts to the west are at the base of the quartzite east and west of Teal Lake. At one place here the relations are such that the layers of the conglomerate cut across the foliation of the subjacent schists at an acute angle. Still farther west, in Sec. 30, T 48 N, R 28 W, contacts are found in a number of places. West of this point the only actual contact known is north of the Michigamme mine.

The unconformity between the Lower Marquette and Upper Marquette series is also well marked. At the close of Lower Marquette time the land was raised above the sea, gently folded and eroded, and the Upper Marquette sediments were later laid down unconformably upon this floor. In general the discordance between the Lower Marquette series and the succeeding series is not great, being measured frequently by five to ten degrees, at other times by ten to fifteen degrees, and it is only rarely that the plications of the lower series are such as to make the beds abut perpendicularly against those of the overlying series. Erosion has cut deeper in the Lower Marquette series in some places than in others, so that the Upper Marquette series rests upon different members of the lower series. At the east end of the area it left a very considerable thickness of the iron-bearing formation, but in places to the west this formation is quite cut out. Indeed, in places erosion cut through the Siamo slate and the Ajibik quartzite, and in some places even into the Basement Complex. This

particularly occurs in the west and southwest parts of the district, west of Champion and along the Republic Trough, where but few members of the Lower Marquette series were deposited. Even within a short distance the differential erosion was considerable. For instance, at the south end of the Republic Trough the variation was more than 1500 feet.

The Marquette district has been folded in a complex manner. The largest but least conspicuous fold of the district is an anticline having a north-south axis, running through the city of Marquette. This great fold has, especially near its crown—that is, for the eastern six or eight miles of the district—folds of the second order superimposed upon it, making this part of the fold an anticlinorium. The other major anticline belonging to this system of folds is one running north and south through the east end of Michigamme Lake. The major part of the district has been affected, however, by much more effective pressure in a north-south direction, so that the folds in an east-west direction are much more conspicuous than the north-south folds of greater wavelength and greater amplitude. As a result of the north-south pressure, the Upper and Lower Marquette series together have been bent into a great abnormal synclinorium. This synclinorium is of a peculiar and complicated character. The Algonkian rocks on either side of the trough have moved over the more rigid Archean granite, and, as a consequence, on each side of the Algonkian trough a series of overfolds plunge steeply toward its center, producing a structure resembling in this respect the composed fan structure of the Alps. There is, however, this great difference between the Marquette structure and that of the Alps, that in passing from the sides of the trough toward the center, newer rocks appear rather than older ones, so that in the center of the synclinorium the youngest rocks are found. It is as if the composed fan folds of the Alps were sagged downward, so that the structure as a whole is a synclinorium rather than an anticlinorium. This form of folding has been elsewhere defined by Van Hise[1] as an abnormal synclinorium. The folding is closer in the western part of the district than to the east. The strikes of most of the exposures of the district are mainly controlled by the east-west folds, but, at the east and west ends of the areas of the formations, the larger north-south folds already described control.

[1] Principles of North American Pre-Cambrian geology, by C. R. VAN HISE, 16th Annual Report U. S. Geol Surv., Part I, 1896, p. 612.

The rocks of the district have yielded to the folding in different ways. Where brittle the close plications have resulted in their being fractured through and through, and in many places they pass into reibungsbreccias. These phenomena are particularly prevalent in the Negaunee iron formation and in the quartzites. The more plastic formations have yielded without major fracturing, but in a minor way they show everywhere the effects of deformation. A microscopical study shows that not a cubic inch of material has escaped dynamic action. While, as a further consequence of dynamic action there has been local faulting at various places, with two or three exceptions, no important faults have been observed in this district.

Because of the varying strength and texture of the various beds and formations, the readjustments necessary in folding took place in large measure between the different formations and between dissimilar beds of each formation. As these layers were rubbed over one another, schistosity was developed parallel to the bedding in many places. The unconformable contacts between the Upper Marquette and Lower Marquette series, and between the Archean and Lower Marquette series, were the greatest planes of movement, and adjacent to them the rocks of both the series were rendered schistose. In the nearly homogeneous Michigamme and other slates there apparently occurred an actual flowage. Here there is frequently a discordance between the cleavage or schistosity and the bedding.

It is inferred from the phenomena of deformation that, when folded, the rocks which are now at the surface were buried under a thickness of several thousand feet of sediments, not impossibly as much as ten thousand feet. On the other hand, it appears that the formations were not so deeply buried as to be beyond the sustaining strength of strong rocks like quartzites, or else the layers of these rocks would have been folded without the production of reibungsbreccias, as in the case of the Doe River quartzite of Tennessee.

As shown by the above facts, the Marquette district furnishes a beautiful instance of deformation in the lower part of the zone of combined fracture and flowage.[1]

The Lower Marquette and Upper Marquette series are correlated with the Lower Huronian and Upper Huronian series of the north shore of Lake Huron. The reasons are stated in previous publica-

[1] Principles of North American Pre-Cambrian geology, by C. R. VAN HISE. 16th Annual Report U. S. Geol. Surv., Part I, 1896, pp. 601–603.

tions, and are not repeated.[1] The succession in the Menominee district of Michigan, as given by Smyth,[2] is compared with that of the Marquette district, and points of similarity and difference noted. It is shown that the series of the two districts may be roughly correlated, but that closer correlation may not be attempted until more detailed studies are made in the Menominee district.

Newett[3] gives a sketch of the Marquette iron-bearing district of Michigan, and publishes a geological map of the district compiled from a map of the Upper Peninsula in the possession of the Michigan Geological Survey. The iron ores occur in the Huronian rocks, of which there are some thirty members. This series of rocks has been subjected to enormous lateral pressure, resulting in foldings in the strata. In the folds the ore is found generally in lenticular masses. The Huronian rocks are cut by eruptive rocks, which have played an important part in assisting in the concentration of the ores.

Gresley[4] describes peculiar markings in iron ore from the Chapin mine of Iron Mountain, Mich., which are thought by H. S. Williams, by Schuchert and by Walcott to be trails of organic origin.

Comments.— At various places in the Menominee district, including the Chapin mine, the Cambrian sandstone unconformably overlies the ferruginous schists of the Huronian. At some localities the lowest horizon of the Cambrian is an iron ore, which has been mined. The question arises whether or not the organic remains referred to by Gresley are contained in the original ore of the Huronian or in the detrital ore of the Cambrian. As the specimens were found in the ore after it had been shipped from the district, it seems impracticable to answer this question, and therefore it is unsafe to conclude that the organic markings are of pre-Cambrian age.

[1] Correlation papers — Archean and Algonkian, by C. R. VAN HISE. Bull. U. S. Geol. Surv., No. 86, 1896, pp. 183–186.

Principles, cit., pp. 796–799.

[2] The Lower Menominee and Lower Marquette series in Michigan, by H. L. SMYTH. Am. Jour. Sci., 3d series, Vol. XLVII, 1894, pp. 216–223.

[3] The Marquette Iron Range of Michigan, by G. A. NEWETT. Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 87–108. With geol. map.

[4] Organic markings in Lake Superior iron ores, by W. S. GRESLEY. Science, new series, Vol. III, 1896, pp. 622–623.

Van Hise[1] describes baselevels in the crystalline rocks of central Wisconsin and Keweenaw Point. In the Wisconsin district the Archean and Huronian rocks occupying the area are truncated to an even baselevel with an apparent southerly slope. The altitude is about 1450 feet.

On Keweenaw Point the peaks of the main trap range rise to so nearly the same altitude that they form an apparent plain, which is considered an ancient baselevel. The altitude of this plain is about 1350 feet. Certain peaks, consisting of hard quartz-porphyry and felsite, have resisted weathering, and stand above this plain.

The central Wisconsin plain has not been so deeply dissected as the Keweenaw Point area, but this is explained by the fact that it is not so near either of the great lakes, and therefore erosion has not been so effective over it.

From the proximity of the central Wisconsin and Keweenaw Point baselevels, and from the fact that they have nearly the same altitude, it is concluded that the baselevels of the two districts are probably but parts of a far more extensive baseleveled region resulting principally from the subaërial erosion of Cretaceous time, and perhaps also, in part, from the marine denudation of the Cretaceous.

Hubbard[2] describes the relation of the copper vein at the Central mine, Keweenaw Point, to the Kearsarge conglomerate. The veins of Keweenaw Point belong largely to one system, and are confined principally between T 57 N, R 32 W, and the northeast extremity of the Point. The copper-bearing formation between these limits dips N 33° E, at the first locality, to south of east at the last, and the veins are nearly at right angles to the formation. The Central mine is situated in Sec. 23, T 58 N, R 31 W, about eighteen miles northeast of Calumet. Here there has been a northerly sliding of the formations above the Kearsarge conglomerate, as a result of which the copper vein in the overlying formations is found to stop abruptly at the Kearsarge conglomerate. In this mine is the eastern edge of the basin in which the Kearsarge conglomerate was deposited.

[1] C. R. VAN HISE, A central Wisconsin baselevel, Science, Vol. IV, 1896, pp. 57–59; A northern Michigan baselevel, *ibid.*, pp. 217–220.

[2] The relation of the vein at the Central mine, Keweenaw Point, to the Kearsarge conglomerate, by L. L. HUBBARD, Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 74–83.

Winchell, H. V.,[1] gives a brief sketch of the iron ranges of Minnesota. Along the north side of the Mesabi range is a ridge of Archean syenite and granite, flanked on both sides by crystalline and semi-crystalline schists. This ridge is called the Giant's Range. On the south side of the Giant's Range, lying at times nearly up to its summit, are the outcropping edges of Taconic or Upper Huronian strata, which overlie unconformably the syenites and schists. These are in turn overlapped to the south by eruptive rocks of Keweenawan age and by Cretaceous sediments. The ore is soft hematite, which lies at low angles from the horizontal, usually covered merely by drift.

The geology of the Vermilion Range is not yet understood. The iron ores are solid and massive, except at the Chandler mine, where they are brecciated, and occur in steeply inclined lenses between walls of schist, extending to an indefinite depth.

Lawson[2] describes a family of basic plutonic orthoclase rocks rich in alkalies and lime, which he names malignite, as occurring in the form of a laccolite in the Coutchiching schists of Poohbah Lake. The malignites vary from basic nepheline-pyroxene malignite through garnet-pyroxene malignite to amphibole malignite.

Coleman[3] makes a second report on the gold fields of western Ontario, including the area between Finmark, near Thunder Bay, and the Manitoba boundary, and between Minnesota and Keewatin on the north shore of Lonely Lake. This visit confirms his impressions of the geology of the area as given in the preceding report of the bureau.[4]

At many places the Laurentian rocks show an eruptive contact with the overlying rocks, showing that they must have been consolidated later than the Huronian. Coleman suggests that it would be more logical to confine the name *Laurentian* to the oldest complex of thoroughly crystalline rocks serving as a foundation for all succeeding rocks, and to describe the clearly eruptive rocks which penetrate the

[1] The iron ranges of Minnesota, by H. V. WINCHELL, Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 11–32.

[2] Malignite, a family of basic plutonic orthoclase rocks rich in alkalies and lime, by ANDREW C. LAWSON, Bull. Dept. of Geol., Univ. of Cal., Vol. I, 1896, pp. 337–362, Pl. 18.

[3] A second report on the gold fields of western Ontario, by A. P. COLEMAN, Fifth Rept. Bureau of Mines, Ontaria, for 1895, Sec. II, pp. 47–106, 1896.

[4] Reviewed in this JOURNAL, Vol. IV, pp. 744–745.

overlying Huronian schists as eruptives, of later age than at least the earlier members of the Huronian. If this were done, very little of the territory under consideration could be mapped as Laurentian —perhaps none of it with certainty. However, the discrimination may not be made until more detailed work has been done in the district.

Coutchiching mica-schists and gneisses, though probably present, have not been certainly recognized. The series of eruptives, pyroclastics, and less common waterworn clastics, Lawson's Keewatin, is of widespread occurrence, and of great importance as containing the gold-bearing veins of the district. It is spoken of under the general term Huronian.

Blue[1] sketches the geological history of the New Ontario, which includes that part of the province of Ontario lying beyond the Matawan and French rivers, and the Nipissing, Huron, and Superior lakes, to the north and west boundaries of the province. Laurentian and Huronian rocks form highlands which in Archean time were the most important physical feature of North America, sweeping in a curve through what is known in our time as the regions of Labrador, Quebec, Ontario, and the Northwest Territories. While there are large areas in which eruptive masses of granite and gneiss have penetrated the Huronian rocks, and thrown them into folds, proving their later age, in general the reverse is the case, the Huronian resting unconformably upon the Laurentian, and being of later origin. The Huronian is overlain unconformably by Cambrian rocks, under the Cambrian being included Animikie, Nipigon, and Potsdam rocks.

Comments.—The term *Cambrian*, as here used, covers Animikie, Keweenawan, and Potsdam rocks. The two former have ordinarily been regarded as pre-Cambrian.

Dowling[2] reports on the geology of the country in the vicinity of Red Lake and part of the basin of Berens River, in the district of Keewatin, Canada. The rocks exposed are all Archean, including gneisses

[1] The New Ontario, by ARCHIBALD BLUE. Fifth Rept. Bureau of Mines, Ontario, for 1895, pp. 193–196, 1896.

[2] Report on the country in the vicinity of Red Lake, and part of the basin of the Berens River, District of Keewatin, by D. B. DOWLING, Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part F, 1896, pp. 54. With geological map.

and granites classed as Laurentian, and folded schists and greenstones classed as Huronian.

The Laurentian rocks prevail over a much greater area than the Huronian rocks, being seen along the White and Berens rivers, on Lac Seul, and on the English and Matawan rivers. They are gneisses and granites, the latter in places apparently intrusive in the former, as along the headwaters of the Berens River. The granites are occasionally intrusive also in the Huronian to the south.

The Huronian rocks are a series of schists, limestones, and water-deposited volcanic materials. They occur in two main areas. The eastern one is in the vicinity of Clearwater and Woman lakes. The eastern boundary of this area has not been defined; to the west, the Huronian is in contact with the Laurentian. From the southwestern part of the area, a belt extends southwest to the vicinity of Shallow Lake. The western area of Huronian occurs in the vicinity of Red Lake, and is surrounded by and incloses areas of Laurentian granite and gneiss.

Contacts of the Laurentian and Huronian rocks are described for numerous localities. The contacts are "generally of a brecciated character, the gneisses and granites while in a plastic condition surrounding and inclosing the Huronian schists" (p. 40).

The Huronian rocks are similar in many respects to the Keewatin series of the Lake of the Woods and Rainy Lake districts, to the south: but the Huronian of the area under discussion includes dark blue limestone, and conglomerates with jasper pebbles, both very similar to those of the typical Huronian area north of Lake Huron, and the rocks are accordingly mapped as Huronian.

The Coutchiching, supposed by Lawson to underlie the Keewatin of the Rainy Lake country, is possibly here represented by a small area west of Shallow Lake, mapped as Huronian. However, at Gull Rock Lake, rocks which still more resemble the Coutchiching of the Rainy Lake region are found to be but highly altered Huronian beds in contact with the Laurentian, which, when followed along the strike, take on the general aspect of the remainder of the Huronian of the district.

GENERAL COMMENTS.

In the articles by Blue, Coleman, and Dowling the term *Laurentian* is used to cover both the ancient basement upon which the Huronian rocks were deposited, and later granitic intrusives, although Coleman

recognizes the fact that the logical course is to confine the term Laurentian to the older rocks. This usage of the term is a serious obstacle to the progress of structural geology in this region, for two entirely different series of rocks are confused. Plainly the rocks called Laurentian upon which the Huronian was deposited are pre-Huronian; it is equally certain that the granites called Laurentian which cut the Huronian are Huronian or post-Huronian in age. So long as these two classes of rocks are confused on the maps, no such thing as a structural map of the area northwest of Lake Superior is possible.

C. K. LEITH.

Reviews.

Elemente der Gesteinslehre. By H. Rosenbusch, Stuttgart, 1898.

That this book presents the essential features of Professor Rosenbusch's lectures on petrology as they have been developed during thirty years of his experience, is sufficient guarantee that the work is a most valuable contribution to the didactic side of the subject. That those who are not permitted to listen to Professor Rosenbusch in Heidelberg may read his careful presentation of the essential characteristics of rocks is fortunate, and the appearance of the book so long looked for is a fact upon which many may congratulate themselves. No satisfactory review of a work so full of matter can be given without close and exhaustive reading, but some insight into its character may be gotten without exhausting the subject.

In attempting to condense the wide range of facts and speculations relating to igneous, sedimentary and metamorphosed rocks into the space of an elementary text-book, minor details and qualifications of statements are minimized or omitted, thereby sharpening the outlines of the images presented to the mind. As a necessary result we find in some cases positive statements where we should expect tentative ones, and a tone of finality in portions of the work where we had not expected it. This is of course noticeable in the introductory portions of the parts devoted to the three categories of rocks.

The general introductory chapter, after defining a rock, and the scope of petrology, treats of the methods of investigating rocks, geologically, mineralogically and chemically, special attention being given to the chemical characteristics. Definitions of the principal terms used in connection with the mineral constituents are followed by an account of varieties of parting and jointing of rocks and a brief statement of their formation and classification.

Part I deals with eruptive rocks, first considering their constituents as chemical compounds and as minerals, and the relation of the latter to one another both as to the order of their crystallization and as to their morphology. Then their geological characteristics are described.

Considerable space is given to their texture or structure, with special reference to their interpretation in terms of the occurrence of the rocks and the order of crystallization of the mineral constituents. The age of igneous rocks and their alteration and metamorphism are briefly treated, and a system of classification is given without discussion of the principles on which it is based. The classification followed is the same as that employed in Professor Rosenbusch's work on the Microscopical Physiography of the Massive Rocks, with slight modification in the divisions embracing "*Tiefengesteine*" and "*Ganggesteine.*" An age distinction has disappeared from the grouping of "*Ergussgesteine,*" so that liparite and quartz-porphyry are described together.

The description of each class of rocks embraces the mineralogical and microscopical characteristics, besides the chemical composition, which is shown in ample tables of analyses both of the rocks as a whole and of separate mineral constituents. This feature is a very marked addition to the treatment of the subject in the Microscopical Physiography of Massive Rocks. The metamorphism of igneous rocks themselves and that produced by them upon adjacent rocks is described in immediate connection with the description of the unaltered rocks.

The part devoted to stratified rocks follows the same general plan as Part I. The rocks are classified under the heads of: precipitates, psephites and psammites, silica rocks (not previously described), carbonate rocks, iron rocks, clay rocks, porphyroids and fossil fuels. In this part also, considerable is introduced that belongs to the subject of metamorphism.

Part III treats of the crystalline schists, their composition, geological occurrence, texture and classification. Crystalline schists are said to be eruptive or sedimentary rocks that have attained geological transformation chiefly through the coöperation of geo-dynamic agencies. The classification of these rocks is that commonly used and the author recognizes its artificial and unsatisfactory character but considers our knowledge and judgment in the matter not yet sufficiently advanced to warrant any attempt at its betterment at this time. The order followed is: gneisses, mica-schists, talc-schists, chlorite-schists, amphibole and pyroxene rocks, serpentine, rocks of the lime series, magnesia series, iron series, and emery (corundum). In each class the mineral and chemical compositions are described together with the texture and the varieties of rock embraced within each class.

Whatever may be our view of the position taken by Professor Rosenbusch upon certain mooted questions in petrology, we must acknowledge the great value of this recent work, and congratulate the author upon its publication. J. P. I.

A Text Book of Mineralogy with an extended treatise on Crystallography and Physical Mineralogy, by E. S. DANA, New York, John Wiley & Sons, 1898.

This is a new edition of Professor Dana's former text-book entirely rewritten and enlarged. It consists of four parts devoted to crystallography, physical mineralogy, chemical mineralogy, and descriptive mineralogy, and contains an appendix treating of the drawing of crystal figures, and of projections, besides one giving tables to be used in the determination of minerals.

The relation of crystal form to other physical properties and to the probable molecular structure of crystals is set forth in the introductory paragraphs of Part I, and the grouping of the crystal forms is made in relation to the thirty-two classes of symmetry. For this reason it would seem that a more logical arrangement of the subject would place the physical mineralogy first and the crystallography afterwards.

The arrangement of the types of crystal forms although referred to the classes of symmetry is the order usually employed in elementary treatises, namely, the group with the most complex symmetry first. The necessity for this order of arrangement is questionable.

The treatment of the six crystallographic systems is quite full and in addition to the description of the symmetry and principal forms are given their spherical projection and the mathematical relations of each system. Compound or twin crystals and the irregularities of crystals are described at length and are profusely illustrated.

The physical characters of minerals are treated briefly in connection with those of cohesion, elasticity, and relative density, as well as those related to heat, electricity, and magnetism. The optical properties are considered at greater length, both as to the principles involved and their application to the optical investigation of minerals. In this respect the improvement over former editions of the Text Book is marked. The part devoted to chemical mineralogy includes a statement of the general principles of chemistry which apply to minerals

and a brief description of methods of chemical examinations of minerals.

The descriptive mineralogy is an abridgment of the sixth edition of Professor Dana's System of Mineralogy and possesses most of the advantageous features of the larger work. However, much of the material of the latter work is necessarily excluded from a text-book.

Perhaps the most striking feature of the new edition of this Text Book of Mineralogy is the condensation of the material, a great amount of information being compassed by so few pages. Its adaptability for class instruction, however, has yet to be tested, and it is hoped that it will prove satisfactory. Its need has been long felt and Professor Dana is to be thanked for its preparation. It is regrettable that the figures used for illustration vary so greatly in merit. While most of them are excellent, some are quite defective or are poorly printed so that the lettering is obscure or the edges of crystals confused.

J. P. I.

Manual of Determinative Mineralogy with an introduction on Blowpipe Analysis, by GEORGE J. BRUSH. Revised and enlarged, with entirely new tables for the identification of minerals, by Samuel L. Penfield. Fifteenth edition. John Wiley & Sons, New York. Chapman & Hall, London, 1898.

In 1896 a revision of the introductory chapters of this book, relating to blowpipe analysis and the chemical reactions of the elements, was published, and was reviewed in this JOURNAL, Vol. V, p. 86. The character of the work published at that time was of so high an order as to raise expectations regarding the promised revision of the tables for the identification of minerals. These expectations have been fully satisfied by the present publication. The advancement of mineralogical knowledge since the tables were first arranged in 1874 by Professor Brush has necessitated their expansion and rearrangement and has permitted of their being rounded out into more perfect form. The new tables are not only almost double the length of those published two years ago, but are more complete in the amount of data furnished under each mineral species. And, while the number of species of minerals in the new tables is much larger than formerly, the student is saved from confusion by the printing of the commoner kinds in stronger type than that used for the rarer ones. There are frequent

evidences of the care taken by the author to prevent errors on the part of the student, and, with the detailed methods of procedure described in the introductory chapters, it would seem as though everything had been done to enable the student to fit himself to identify minerals by all means except those based on their optical behavior in polarized light.

A chapter has been introduced into this edition treating of the crystal forms of minerals in a manner especially adapted to beginners. The treatment is necessarily brief as regards the principles of crystallography. Particular stress has been put upon the illustration of the subject. The number of figures is not only large as compared with the extent of the text, but care has been taken to employ examples most likely to be met with by the student, and the drawing of the figures has been well done. The method of treatment is mainly descriptive, and, though conceptions of symmetry are introduced, and excellent figures representing the relative positions of different axes of symmetry are given in connection with various subdivisions of crystal forms, the application of symmetry to the forms or its relation to them is left to the student to work out. The arrangement of the groups or systems of crystal forms is that ordinarily followed, beginning with those having the most complex symmetry, holohedral isometric crystals, and finishing with crystals without symmetry, the triclinic. Subdivisions of each of these systems are called normal, when holohedral according to former usage, and when having less symmetry than the highest in each system, that is, when belonging to what have been called hemihedral or tetartohedral, they are named after some characteristic crystal form or after some mineral characterized by such a form.

In all parts of the book there are evidences of the great care taken by the author to render the subject intelligible to persons taking up the study of minerals for the first time, and there can be no question as to the success of the endeavor. J. P. I.

The Lower Cretaceous Gryphæas of the Texas Region. By ROBERT THOMAS HILL and THOMAS WAYLAND VAUGHAN. Bulletin No. 151, U. S. G. S. Washington, D. C.

The bulletin presents a careful study of that group of fossil oysters which has generally been referred to *Gryphæa pitcheri* of Morton. The authors vigorously criticise the opinions and descriptions formerly

published, and dwell with laudable earnestness upon the confusion resulting from carelessness and from opinions based upon inadequate investigation. The great variability of the *Ostreidæ* is emphasized, but the authors correct the opinion previously held that this variability destroys their value in stratigraphy. They show that the hemeræ of many forms have well defined limits and are, therefore, of the greatest use in determining horizons. No classification yet given is satisfactory for the Texas *Ostreidæ*. The forms are tabulated provisionally under the old familiar names.

After this discussion, which deals in some measure with the family in general, the authors confine their attention to the specific object of the paper. The various forms which have been referred to *Gryphæa pitcheri* are discussed from a historical standpoint and their stratigraphic and geographic distribution noted. The species of the group are specifically defined and many data given regarding their development and methods of growth, and lastly, something of their phylogeny. A large part of the bulletin is taken up with plates showing the various species at different stages of growth and the individual shells in different positions. The figures formerly published are also reproduced for comparison. The work is especially commendable for careful investigation and clear-cut presentation. W. T. Lee.

Le Granit des Pyrénées et ses phénomènes de contact—Premier memoir: Les contacts de la Haute-Ariège, par M. A. Lacroix, Professeur de Minéralogie au Mus. d'Hist. Nat. Bull. des serv. de la carte géol. de la France. No. 64, tome X. Paris, 1898.

The area which has furnished the results published by M. Lacroix in this bulletin is situated in the very mountainous southern tract of the Departement of the Ariège, about 100^{km} southeast by south of the city of Toulouse. The Ariège, one of the head waters of the Garonne, flows through the region. Most emphasis is laid on the phenomena of contact exhibited on the right bank of the stream, since the exposures are considerably more accessible and continuous than on the left bank. The facts of observation on both banks are, however, accordant.

This, the first memoir on the granite massifs of the Pyrénées, is devoted to a purely mineralogical treatment of igneous contacts, which

of itself cannot fail to impress the reader with a sense of the abundant store of facts from which M. Lacroix has drawn his interesting and even startling conclusions. These refer to the prime topics of exomorphic and endomorphic metamorphism and the *mise en place* of the granite, on all three of which the investigations of M. Lacroix shed new light.

The granite occurs in the form of a broad stock stretching some 50^{km} from east to west, and the bulletin refers particularly to the contacts at the western end. The rock is a normal coarse-grained granitite, sometimes, though never at the contacts, charged with phenocrysts of microcline several centimeters long. At the contacts it is filled with an extraordinary number of inclusions of the country rocks.

The latter are composed of slates and quartzites with non-magnesian limestones, either massive or interrupted with interbedded slaty layers. All of these rocks have been affected, often profoundly, by contact metamorphism. To this cause is to be attributed the development of a micaceous character, with garnet, cordierite, and sillimanite common in the contact belt. But the most important determination of this new crystallization is that of the existence of orthoclase and of the triclinic feldspars in the micaceous slate zone (*leptynolites*) in amounts which make the feldspar, either the predominant constituent or less abundant, even to its appearing only as scattering grains. This feldspathization has occurred by the process of "imbibition" or by the injection of minute granite apophyses *lit par lit*. The quartzites are similarly feldspathized and rendered micaceous, though in less marked degree than the slates. The white and black limestones, on the other hand, are much more affected, containing grossularite (*grenatite*), vesuvianite, various pyroxenes and amphiboles, epidote (*epidotite*), and the triclinic feldspars from oligoclase to anorthite (*Cornéennes feldspathiques*). Marmorosis is common. On p. 48, M. Lacroix has given a clear statement of the theory of feldspathization and of the part played by the *agents minéralisateurs* in the recrystallization of metamorphic belts. As is well known, he is at one with MM. Fouqué, Michel Lévy, Barrois and others who contend for an actual migration of granite substance from an intrusive granite stock in the presence of mineralizing agents, into the country rock, as well as for the possible removal of certain elements in the exomorphic contact zone under the same conditions of intrusion. A detailed argument for this position is given in Chapter III; its analysis would be beyond the scope of this review.

It is particularly in the study of endomorphic contact action that the bulletin demands the attention of petrographers. While the slates do not seem to have exerted any very pronounced effect on the granitite except in the way of slightly altering its structure, the limestone contact is one pronounced, both from the quality of the changes wrought and from their great areal extent, to be the most noteworthy phenomenon of the region. By the assimilation of the limestone, the granitite successively loses the alkaline feldspars, orthoclase, microcline and anorthoclase, and lastly, quartz, and gains other constituents rich in lime, the basic plagioclases and hornblende. The result is to produce a gradual replacement of the pure granitite magma in the massif by secondary mixtures which have crystallized out as hornblende-granitites, quartz-diorites, diorites, norites and hornblendites. Biotite and hornblende appear in the whole series. When, finally, olivine replaces all the feldspars, the resulting rock, though again the product of assimilation in the same way as the more acid rocks just enumerated, is an amphibole peridotite! The evidences for the fact of magmatic incorporation are exceptionally strong; they may be summarized as follows:

1. Field observations in connection with many localities of actual contact and the study of numerous thin sections showed ordinarily an insensible transition in mineralogical characters from the normal granitite to the basic types.

2. These hornblende rocks are developed only in zones of contact between typical granitite and the limestone, or else in bands which represent the prolongation of limestone layers stretching out into the granitite—a significant mode of occurrence emphasized in the memoir. Such basic bands, extending through the granitite from one end of an interrupted limestone layer along its strike to the corresponding end on the other side of the stock, are interpreted as being the product of recrystallization of mixed granite magma and digested limestone during a prolonged static condition of the igneous rock—that is, a period of quiescence as regards ascensional or lateral movement in the mass. It is hard to resist the conclusion that the map and numerous cross-sections of M. Lacroix prove such a long continuance of the limestone in contact with the particular magma now crystallized and visible where erosion has laid bare the zones of passage; and, moreover, that this fact explains the peculiarly favorable case for the proof of assimilation. The present reviewer is of opinion that the lack of

evidence for clearly defined endomorphic action leading to serious modification of eruptive magmas is, in many cases, due to a removal of the mixed zone of assimilation from contacts by bodily movement of the magma. Such a period of active assimilation and removal is followed by another of limited or no power of assimilation, during incipient cooling, and that stage by a third marked by the crystallization of essentially pure magma in contact with country rock, perhaps metamorphosed but not incorporated.

3. A striking argument for the modification of the granitite in this manner is afforded by certain inclusions within it, described as surrounded by the hornblendic basic types identical with those characterizing the main contacts.

4. No independent dikes, apophyses, or stocks of the basic rocks occur in the region, and on the right bank of the Oriège, at least, there is no dynamic action sufficiently intense to explain the presence of diorites, etc., in the granitite by any system of cross-faults.

5. Lastly, the absence of chilling phenomena in the stock, the intensity of the exomorphic metamorphism, the enormous number of apophyses in the slates, as well as other facts, all tend to show a condition of high temperatures for a long period, and of abundant mineralizers which are permissive of the large amount of recrystallization necessary to explain the occurrence of the basic rocks.

The mode of intrusion is implied in what precedes — a *mise en place* by progressive assimilation of the overlying terranes. The proofs of absorption of the quartzites and slates are not so strikingly manifest as those in the case of the limestone, but they are regarded by M. Lacroix as equally valid. On the other hand, neither block-faulting, nor the batholithic, nor the laccolithic hypothesis seems to be admissible.

On the whole, the memoir is seen to have its chief importance in upholding first, the doctrine of feldspathization of the metamorphic aureole about an intruded granite by the addition, in the presence of mineralizers, of feldspathic material from the granite's own mass; secondly, the doctrine of assimilation; and, lastly, the theory of the *mise en place* of intrusive granites, as enunciated by M. Michel Lévy. It is safe to say that, from the point of view of field observations and of comparative mineralogical study, these tenets of the French school of petrographers have never had in a single locality such strong confirmation. We shall look forward with interest to the forthcoming memoir

on the chemical relations of the rocks of this region. It may be that the analyses will explain certain difficulties which have suggested themselves, almost as a matter of course, in the way of explaining the formation of such minerals as hornblende and olivine (especially the latter) in the endomorphic zone of recrystallization. R. A. DALY.

RECENT BIBLIOGRAPHIES.

Bibliography and Index of North American Geology, Palæontology, Petrography, and Mineralogy for 1896. By F. B. WEEKS. (Bull. U. S. Geol. Surv., 149, 152 pp. Washington, 1897.)

Bibliografia Geológica y Minera de la República Mexicana. By R. AGUILAR y Santillán. (Bol. 10, Inst. Geol. de Mexico. 158 pp. Mexico, 1898.)

Students and workers in geology everywhere will be glad to receive the two papers here mentioned. The value of a well compiled and carefully edited bibliography is too well recognized to need any mention. To all active workers such books are indispensable. The two under review, fortunately, are both excellent. Mr. Week's good work in this line needs no introduction. It only remains to commend and to note the broadened scope of the bibliography. In its preparation 108 serials were examined, the number including several devoted to economic phases of geology and not previously listed. As usual the abstracts are concise, but are quite sufficient to determine the scope of the paper. The full indexes are especially valuable.

The bibliography of Mexico is especially helpful, because of the previous absence of any paper thoroughly covering the field. The author has had more than the usual difficulties, due to poor library facilities, the scattered and incidental nature of the papers, and the presence of broken sets of short lived serials. In the face of such materials there must necessarily be a certain amount of selection. Not all the papers listed are strictly geological but all will doubtless be helpful. At first glance the 1953 titles included seem formidable, and one is surprised at the amount which has been written, but a more careful examination shows, as remarked by the Director in his introduction, that the great majority of the papers written on the geology of Mexico are really technical engineering papers, and deal with geology

but incidentally. The present active geological survey of Mexico has a practically new field, and in view of this and the difficulties of communication over much of the republic, the rapidity of its publication and the high class of the work, deserve the heartiest recognition. Among the publications of the survey the present one will for sometime to come rank among the more useful. H. F. B.

Geological Survey of Kansas, Vol. III, 1898. By DR. E. HAWORTH, geologist, and MR. W. R. CRANE, assistant geologist and chemist.

Volume III is a special report on Kansas coals and treats of the coal mines and coal mining of the state in all their various aspects. The volume is divided in two parts.

Part I is by Dr. Haworth and deals with the general stratigraphy of the Kansas Coal Measures. Numerous detailed accounts of the strata are given to enable the reader to understand the general geological conditions of the Coal Measure area of the state. The geology of the area is further shown by the records of many deep wells with drawings illustrating the strata as shown by the wells, and in addition to these many geological sections crossing the state in different directions are given.

The following facts are gleaned from Dr. Haworth's report. The Mississippian or subcarboniferous outcrop occupies an area of about forty-five square miles in the extreme southeastern part of the state. The strata dip under the other formations of the state and their westward inclination is about 17 feet per mile, on the average. The Coal Measures proper occupy the eastern third of the state and constitute a mass of alternating layers of limestones or sandstones and shales aggregating 3000 feet in thickness. The limestones are similar in general character but the lower ones are more nearly crystalline, of finer texture, and denser in appearance. The following divisions of the Coal Measures, named in order from lowest to highest, are recognized: (1) The Cherokee shales; (2) The Oswego limestone; (3) The Labette shales; (4) The Pawnee limestone; (5) The Pleasanton shales; (6) The Erie limestone; (7) The Thayer shales; (8) The Iola limestone; (9) The Lane shales; (10) The Garnett limestones; (11) The Leroy shales; (12) The Oread limestone; (13) The Lecompton shales and Elgin limestone.

Part II of the report is by Mr. W. R. Crane and deals with the detailed stratigraphy as exhibited at the mines, the geographic location of the coal fields, the chemical and physical properties of the coal, mining methods and mining machinery, statistics of coal companies and coal mining laws. It contains the best exposition of the phenomena of "horsebacks" in the coal that has yet been published. The subject is fully illustrated by clear-cut drawings. Mr. Crane thinks the "horsebacks" are the result of fissures produced by vibratory movements of the strata, the fissures thus produced being filled with clay, either by the removal of pressure or by "creeping," these vibratory movements, he thinks, in all probability accompanied the Ozark uplift. Rolls and "bells" and other stratigraphical phenomena are explained.

According to the author there are 15,000 square miles of productive coal fields in Kansas but only a small proportion of this area is being worked at the present time. The mines most extensively worked are located in the southeastern part of the state. Across the coal area the percentage of fixed carbon in the coal and the value of the coal (selling price) increases from northwest to southeast. Coal is mined by stripping, drifting, pitting and shafting. In the shafts mining is carried on by means of "the long wall system" or "the room and pillar system."

To the author's exposition of the chemical and physical properties of the coals the greatest importance is attached. He performed the work in a very elaborate manner, the tests being made in many different ways, all the results of which are finally placed in a general summary. The illustrations of machinery, etc., used in the article are from the pen of the author and attest his ability as a draughtsman.

W. N. L.

Twenty-second Annual Report Indiana Geological Survey. W. S. BATCHLEY, State Geologist, Indianapolis, 1898.

The Twenty-second Annual Report of the state geologist gives a detailed statement of the work of the department of geology and natural resources, for the year 1897. Among the subjects treated in the volume is a paper on the "Geological Scale of Indiana," by W. S. Batchley and Geo. H. Ashley. This paper shows the geological formations of Indiana in vertical section, and gives the time, character of the rocks, and subdivisions of each group.

A paper on "The Geology of Lake and Porter Counties," by W. S. Batchley, is devoted mainly to the physiography of the two counties. The author states that the discussion is limited to this phase of geology "since not a single outcrop of rock occurs in the two counties." A considerable portion of the paper is devoted to the discussion of glacial phenomena.

An economic paper by the same author discusses "The Clays and Clay Industries of Northwestern Indiana." The paper treats in some detail of the origin, varieties, properties, impurities of clays and their analyses. Statistics are also given concerning the clay industry.

"Report on the Niagara Limestone Quarries" is the subject of a paper by August Foerste. This report contains a discussion of the uses, properties, and distribution of the stone. From this paper we learn that the variety known as "Laurel limestone" is the most valuable variety; that it occurs in natural slabs, is easily quarried, requires little dressing, is of a handsome color, and is very hard and durable.

The palæontology of the state receives attention through E. M. Kindle, who has prepared a "Catalogue of the Fossils of Indiana." The report also indicates the geological horizon of the species, and is accompanied by a bibliography of Indiana palæontology.

A contribution to the ornithological literature of the state is found in a paper entitled "The Birds of Indiana," by A. W. Butler. The paper contains descriptions of 321 species which have been identified within the state. It also treats of the songs, habits, and times of arrival and departure, of the birds.

Other papers in the report discuss mines, natural gas, and petroleum.

W. N. L.

Sixth Annual Report Iowa Geological Survey, Vol. VIII. By SAMUEL CALVIN, State Geologist. Desmoines, 1897.

This volume embodies the results of field work covering an area of five counties. An important part of the work has consisted in a careful determination of the location and extent of mineral deposits, clays, building stones, and other economic resources, including a valuable discussion of the drift sheets and other surface formations preliminary to a complete description of the soils of the state.

Of great interest to the people of Iowa will be the tabulated statis-

tics, at the beginning of the volume, relative to the year's economic production. The report closes with a paper on the "Properties and Tests of Iowa Building Stones," by H. Foster Bain, which cannot fail to prove of inestimable local value.

Although the directing motive in the work of the survey has been toward economic and practical ends, this report contains, as have preceding volumes, many discussions of general scientific interest. The treatment of strictly geological features, especially in their physiographic aspects, for thoroughness of preparation and clearness of presentation will prove, beyond doubt, to be a source of great interest to the geologists of the country.

The volume is admirably printed, and besides containing many new maps and diagrams, is judiciously illustrated by an expressive collection of photographs in half tone. J. W. F.

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